The relationship between working memory and creative processes: Evidence of the elaboration of creative strategies in semantic encoding

by

Ioannis Kalaitzidis

MA, BSc Hons (Nottingham University)

BEdu Hons (Patras University)

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Department of International Studies
Faculty of Arts
Macquarie University, Sydney
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Abstract

Working memory is defined as an online limited capacity storage and processing system consisting of: (a) short-term "stores"; (b) processes and strategies; and (c) executive attention. It is a functionally important system for processing a wide range of cognitive activities such as reasoning, learning and comprehension. Creativity involves the creation of an original and useful product. One of the main cognitive processes underpinning creativity is associative processing.

Contemporary studies on human cognition have previously indirectly investigated the relationship between working memory and creativity. The majority of these recent studies hypothesise that working memory is prerequisite for creativity and more specifically, cognitive flexibility, abstract thinking, strategic planning, remote associations, convergent and divergent thinking. However, the main disadvantage of all of these studies is that they do not employ working memory tasks requiring creative abilities. There is no research to date which specifically investigates how creativity and creative strategies can affect the strategies incorporated in working memory processes. However, some assumptions can be indirectly draw from relevant contemporary research. For example, selective attention, which involves the ability to focus cognitive resources on information relevant to goals, has been shown to influence working memory performance (Gazzaley & Nobre, 2012), while both modality dependent working memory mechanisms and modality independent attention control mechanisms do have an impact on insight problem solving (Chein & Weisberg, 2013). Furthermore, Lee and Therriault (2013) link working memory prerformance with the underlying cognitive mechanisms of divergent, convergent thinking as well as associative processing, albeit indirectly. Further indirect support for the association between working memory and creativity comes from neuropsychological studies as well medical studies (Swartwood, Swartwood & Farrell, 2003).

These limitations result in an absence of direct ananlysis of how creativity and creative strategies are related to the strategies incorporated in working memory processes. The main hypothesis of the study, that creative individuals employ creative strategies during specific working memory processing, seeks to correct this gap in research. It was tested against a population sample comprised of 276 adults attending Greek universities. Participants were tested on a battery of tasks including the Remote Associates Test (RAT) and two immediate free recall tasks in Greek, one consisting of

14 sets of semantically similar items and a second consisting of 14 sets of semantically dissimilar items.

The analysis reveals a strong negative correlation (r = –.823) between the difference of performance in the two recall tasks and the RAT. Partial correlation between the RAT score and performance on semantically dissimilar items was positively strong r = .827. These findings indicate that creative individuals employ semantic strategies for demanding tasks whereas less creative individuals fail to adopt demanding/creative strategies. However, correlation between the RAT scores and recall of similar items also revealed a weak negative correlation, r = –.179, indicating that creative individuals are at a disadvantage in recall tasks that facilitate automatic strategies, as they fail to inhibit the flow of irrelevant information. Finally, the findings from this study suggest that creative individuals are flexible in switching between online recall strategies thereby overriding the effects caused by the characteristics of the task.

Declaration

I certify that the work in this thesis entitled "The relationship between working memory and creative processes: Evidence of the elaboration of creative strategies in semantic encoding" has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree to any other university or institution other than Macquarie University. I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research and the preparation of the thesis itself have been appropriately acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. The research presented in this thesis was approved by Macquarie University Ethics Review Committee (Ref No: 5201500489).

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Διά χειρός Ιωάννου Εμ. Καλαϊτζίδη

1. Introduction

1.1 Theoretical and research background — The present study

Working memory is the limited capacity storage system involved in the maintenance and manipulation of information over a short period of time. It is a functionally important system for the facilitation/processing of a wide range of cognitive activities such as reasoning, learning and comprehension (Baddeley, 2003). According to Engle and Kane (2003), working memory is a system of: (a) short-term "stores", assisted by long-term memory traces in a variety of representational formats active above a threshold; (b) rehearsal processes and strategies for achieving and maintaining that activation; and (c) executive attention. According to Baddeley's (2012) multicomponent model, which is the most widely accepted model, working memory is composed of the following four subcomponents: the central executive, the phonological loop, the visuo-spatial sketchpad and the episodic buffer.

The "phonological loop" is a relatively modular system comprising a brief store together with means of maintaining information by vocal or subvocal rehearsal. The "visuo-spatial sketchpad" is divided between a "visual cache", a temporary visual store, and a spatial manipulation and rehearsal system, the "inner scribe". The "central executive" operates in two rather separate ways. One is based on crystalised habits or schemata, demanding little attentional control. This source of control can be overridden by a second process, the supervisory attentional system, which responds to situations that are not capable of being handled by crystalised processes. The fourth component, the episodic buffer, allows incorporation into working memory representations from the long-term memory. The episodic buffer is assumed to hold integrated episodes or chunks in a multidimensional code. Its main operation is to operate as a buffer store, not only between the different components of working memory — phonological loop, visuo-spatial sketchpad and central executive — but also as a connection between working memory components and long-term memory operations and representations.

Research into working memory, specifically into item recall, has shown that items and words are more successfully recalled when they are all drawn from the same semantic category (for example, all of the items in a list are musical instruments or animals) (Baddeley, 2007).

Studies of working memory, particularly verbal short-term memory, have so far mainly involved immediate item recall or immediate serial/free recall of words: for

example, semantically related or unrelated/words or non words. In terms of common methods of investigation and analysis, immediate free recall tasks usually require participants to study a list of items, after which they are prompted to recall the items in any order. In contrast to immediate free recall, the immediate serial recall paradigm refers to a type of investigation where participants are asked to recall presented items in their correct order rather than the order that comes to mind at the time of testing, that is, randomly (Baddeley, 2012).

The initial findings of prior working memory studies suggest that participants' performance in relation to relevant tasks of immediate recall is affected by the phonological properties of the presented stimuli. The aim of these previous studies has been to concentrate on phonological factors. The main investigated effects have been the phonological similarity effect (Baddeley, 2007), the stimulus/word length effect (Baddeley, 2012), the effect of articulatory suppression (Jones, Hughes & Macken, 2006), the irrelevant speech effect (Klatte, Lachmann, Schlittmeier & Hellbruck, 2010), the interaction between articulatory suppression and similarity, irrelevant speech and word length (Baddeley, 2012), and finally, the recency and primacy effects (Bauml & Hartinger, 2002; Anderson, Green & McCulloch, 2000) as well as the temporal clustering effect (Kahana, 1996). The findings of these studies indicate that participants' performance in relevant tasks of immediate recall is affected by the phonological properties of the presented stimuli. However, while these studies have effectively contributed on the development of the aforementioned scientific area, interpretation of their findings and the applied methodologies have not allowed the extensive and exclusive investigation of all the relevant factors (Saint-Aubin, Ouellette & Poirier, 2005).

Recent research with improved design supports the idea that non phonological factors, or psycholinguistic or semantic variables, participate equally with regard to working memory or verbal short-term memory alongside with the already presented phonological factors. Some indicative but not exclusive effects are the lexicality effect (participants recall words more successfully than non words in immediate recall tasks: Majerus, van der Linden, Mulder, Meulemans & Peters, 2004) and the frequency effect (participants recall high-frequency words more successfully than low-frequency words in immediate recall tasks: Woodward, Macken & Jones, 2008). In relation to first and second language speakers it has also been observed that there is a better recall performance for first versus second language material in second language learners and

bilinguals (Thorn, Gathercole & Frankish, 2002; Chincotta & Hoosain, 1995; Service, 1992). The same effect is still observable after training. Nevertheless, overall recall does increase due to an increase of the long-term memory engagement (Messer, Leseman, Boom & Mayo, 2010; Hulme, Maughan & Brown, 1991).

Verbal information encoding in working memory tasks is a consequence of automatic and/or controlled, attention demanding mechanisms of strategic retrieval and encoding (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Research on the retrieval of verbal items supports the distinction between a fast, automatic activation of mainly phonological or partially semantic representations and a slower, more controlled, and effortful mechanism of deep semantic strategic retrieval (Whitney, Grossman & Kircher, 2009; Gold et al., 2006; Badre & Wagner, 2002). Although the use of a phonological strategy for recalling verbal information is considered predominant, under certain conditions or population characteristics the use of a phonological strategy is partially abandoned in favour of a more reliable semantic strategy. Major inconsistencies in working memory performance thus appear to result from switching between phonological encoding and another strategy, probably semantic (Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996).

Some studies have argued that switching between phonological and semantic encoding and recall is possible and observable (Gilhooly, Fioratou, Anthony & Wynn, 2007; Hanley & Bakopoulou, 2003). However, there are contradictions over the question of which type of strategy (phonological and semantic) is applied in specific tasks and their effect gravity as well (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). The ability of a subject to switch between a phonological and a semantic strategy relies on the characteristics of the task, mainly the instructions given and the individual differences between the participants. It is reasonable to presume that this distinction also applies to working memory, indicating that the creative strategies that underpin creative behaviour might have also a significant effect in encoding and recall processes.

Further to the contradictions between phonological and semantic encoding and recall, there are contradictions in the literature over the question of which type of strategy (automatic or controlled) is applied in specific tasks and their effect gravity as well. As Miyake, Friedman, Emerson, Witzki, Howerter and Wager (2000) point out, the evaluation of the employed strategies on working memory tasks has specific weaknesses derived mainly from the individual differences spectrum. They highlight the existence of differences in terms of employed strategies not only between subjects

but also within the same subjects, not only with regard to different tasks but even within the same task:

> complex executive tasks tend to suffer from relatively low internal and/or test–retest reliability. Although the reasons for the low reliabilities are not completely clear, one possibility is that people adopt different strategies on different occasions (or even within a session). Also, the involvement of executive control functions is generally considered strongest when the task is novel (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000, p. 53).

One of the most significant phenomena in semantic encoding is the semantic similarity effect, otherwise known as the semantic relatedness effect. Research into working memory, particularly item recall, has demonstrated that items and words are more successfully recalled when they are all drawn from the same semantic category (for example, all the items of the list are musical instruments or animals) (Baddeley, 2007). Two main efficient tendencies have been developed for the interpretation of the semantic similarity effect, reflecting the tendencies followed in order to explain semantic encoding in terms of working memory. The first tendency indicates that the effect of semantic similarity is related to long-term memory organisation (Saint-Aubin, Ouellette & Poirier, 2005; Poirier & Saint-Aubin, 1995). This explanation focuses on the idea that processing of semantic information in working memory is achieved through the function of the episodic buffer. An alternative tendnecy was developed by neuropsychological research. This approach explains the effect of semantic similarity on the basis of a semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011). According to this view, the encoding processes of semantic information are present within working memory in the form of a semantic buffer (Haarmann, Cameron & Ruchkin, 2003; Haarmann & Usher, 2001; Martin & Freedman, 2001).

To explain the categorical similarity effect Saint-Aubin, Ouellette & Poirier (2005) propose that the item redintegration for lists containing related items is facilitated by participants' long-term knowledge. The category node is implemented as a cue to delimit the number of potential recall candidates within semantic categories and as a consequence the redintegration process is more effective than in the case of dissimilar items. Thus word meanings are retained and accessed by working memory and, more specifically, by the episodic buffer. These processes are independent from phonological and visual codes (Hamilton & Martin, 2005; Shivde & Thompson-Schill, 2004; Baddeley, 2003; Haarmann & Usher, 2001; Baddeley, 2000; Potter, 1993).

In groups of semantically related words the effect of an automatic phonological strategy is likely to be reduced or abandoned in favour of semantic strategic retrieval as the relationship between the items has already been learned and applied (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). In contrast, in regard to the characteristics of the general population with reference to groups of semantically unrelated words, the most obvious and generally adopted strategy is a reliance on phonological encoding (Baddeley, 2007). According to the multicomponent model of working memory, phonological encoding is the main and relatively automatic mechanism in verbal working memory (Baddeley, 2012). The absence of contextual semantic support characterises standard working memory tasks involving the presentation of lists of unrelated words. For lists of semantically similar words an alternative strategy to the typical phonologically based strategy, is a more controlled and effortful mechanism of semantic strategic retrieval, since an automatic semantic retrieval is absent. Such an approach also reveals that the use of automatic or controlled strategies in working memory can rely not only on the characteristics of the task but also more importantly on relevant individual differences factors. Therefore, individuals' abilities in associative processing, the ability to form or recall associations between items, is highly related to creativity. The notion that associative processing is one of the main cognitive processes in creative thinking is well supported (for a review of the relevant literature see review article Lee & Huggins, 2014).

In research literature numerous definitions of creativity have already been proposed (for example, Zeng, Proctor & Salvendy, 2011; Kampylis, Berki & Saariluoma, 2009; and Sternberg, 2003). Mayer's (1999) review of seven definitions provided by authors contributing to the 1999 *Handbook of Creativity* (Sternberg, 2003) concludes that creativity involves the establishment of an original and useful product including ideas as well as concrete objects. In particular, the product must be new and must be given value according to external criteria. The creative idea must be both original and appropriate for the situation in which occurs.

The main cognitive processes underpinning creativity are associative thinking (Benedek, Konen & Neubauer, 2012), divergent thinking (Nusbaum & Silvia, 2011; Cho, Nijenhuis, Vianen, Kim & Lee, 2010), and convergent thinking (Brophy, 2000; Ward, Smith & Vaid, 1997; Finke, Ward & Smith, 1992). Divergent and convergent thinking are well known and supported cognitive mechanisms of creativity. Their distinctiveness has been reported in conjunction with their shared cognitive architecture.

Associative processing is considered as the common element of both convergent and divergent thinking (Rossman & Fink, 2010). For example, the activation and retrieval of remote associations is likely to support divergent processes where the goal is to generate many unusual solutions (for example, "Think of as many uses for a brick as possible": Benedek, Konen & Neubauer, 2012). In contrast, the ability to initiate a wider associative spread and access remote concepts is also likely to promote success on a convergent creative thinking task such as the Remote Association Test (RAT) where the goal is to identify a solution that is distally related to the original stimulus.

Associative processing refers to the activation of mental networks consisting of objectively and subjectively associated concepts or mental items. Associative processing research indicates that the emergence of a creative product requires the activation of associations that are not commonly observed in the population (Turner, Henry & Smith, 2000). This is achieved when a stimulus cues a semantic representation that in turn activates another mental item until the activation reaches the appropriate/effective association (Brophy, 2001). In other words, creative ideas occur when more uncommon elements in lower position in the associative hierarchy are generated or activated. A more analytical reflection of associative processes in creativity research argues that creative products or ideas are generated through the recombination of existing elements. Thus, people scoring low in creativity normally have steep associative hierarchies (that is, the gradient of associative response strength for available associations to a given concept is steep, with only few associations showing high associative response strength), while highly creative people should show flat associative hierarchies. Thus, creative subjects demonstrate more flexible associative links in their mental network and consequently are able to connect or disconnect associative relations more fluently than subjects described as less creative (Rossman & Fink, 2010; Mednick, 1962). This tendency could be one possible reason for the development of more efficient creative problem solving abilities and behaviours.

There are a few studies that have indirectly investigated the relationship between working memory and creativity (Lee & Huggins, 2014). These researchers propose that working memory capacity influences performance in terms of creative tasks that necessitate cognitive flexibility and higher order rules, as well as conscious attention to, and manipulation of, a wide range of cues (Rastogi & Sharma, 2010). The majority of these studies hypothesises that working memory capacity is considered to be a prerequisite for creativity generally and more specifically for cognitive flexibility,

abstract thinking, strategic planning, and processing speed in long-term memory (Deitrich, 2004). The episodic buffer is required for creative thinking and the operation and storage of working memory affects creative problem solving (Baddeley, 2012). Individuals with high working memory capacity are more likely to be successful at overcoming interference caused by automatic, unoriginal responses and also be more effective at using strategies to generate novel approaches and responses with regard to creative thinking tasks (Baddeley, 2007). In other words working memory benefits creativity for it enables the individual to maintain attention on the task and prevents undesirable mind wandering (De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012). Indirect support for the association between working memory and creativity also comes from neuropsychological studies and medical studies. In particular, research reveals that Ritalin (methylphenidate) administration significantly decreases symptoms of attention deficit hyperactive disorder (Swartwood, Swartwood & Farrell, 2003) while improving working memory and creativity. Thus we can see how creativity and working memory are interrelated on the basis of attention.

However, the main disadvantage of these earlier studies is that the majority of them do not employ working memory tasks requiring creative abilities or solutions (Yeh, Lai, Lin, Lin & Sun, 2015). Creative performance is largely dependent on the retrieval, activation, and operation of task-related knowledge (Ward et al., 1999; Yeh, 2011). This methodological gap per se could leave unattended significant areas of research investigating the connection between creativity and working memory. The absence of working memory tasks requiring creative abilities or solutions will reveal how creative processing operates within working memory and thus relevant experimentation will allow the deep investigation of the relevant phenomena (Hanley and Bakopoulou, 2003). In addition, there is no research investigating how creativity, and specifically creative strategies, can affect the strategies incorporated in working memory processes.

Some assumptions can be indirectly based on relevant research. For example, it has been found that selective attention, which involves the ability to focus cognitive resources on information relevant to goals, can influence working memory performance (Gazzaley & Nobre, 2012), while both modality dependent working memory mechanisms and modality independent attention control mechanisms can have an impact on insight problem solving (Chein & Weisberg, 2013). Furthermore, Lee and Therriault (2013) indirectly link working memory performance with the underlying

cognitive mechanisms of divergent and convergent thinking as well as associative processing.

In summary, the reviewed literature reveals specific questions over the relation between working memory and creativity:

- What are the characteristics of the relationship between working memory and creativity?
- Does the relationship between working memory and creativity depend on the referent task and the employed strategies?
- Are creative strategies elaborated on working memory processes?
- Are creative individuals able to switch strategies during specific working memory tasks?

There are thus significant gaps in the literature in terms of examining how creativity and creative strategies are related to the strategies incorporated in working memory processes. Identifying and filling these gaps is the main objective of the present thesis. In the present study, working memory tasks requiring creative abilities or solutions are combined with typical assessments of creativity and verbal working memory tasks (Yeh, Lai, Lin, Lin & Sun, 2015). In particular, 276 monolingual adults studying or having studied in a Greek university participated in the experiment. The present study collects and analyses data relating to their demographic characteristics, their performance on a creativity test (RAT) and their working memory performance in relation to two different immediate free recall tasks. The first immediate free recall task contained semantically similar words while the second immediate free recall task contained semantically dissimilar words. The implementation of two different tasks of immediate free recall allowed the observation of participants' performance in tasks requiring different strategies.

These questions along with the theoretical and empirical evidence of the relevant literature scaffold the main hypothesis of the present study:

- Are creative individuals able to employ different strategies in working memory processing accordingly to the special characteristics of the referent task?

As mentioned above, for the purpose of this study three experimental tasks were used, the RAT for assessing creativity and two different immediate free recall tasks for assessing working memory. The RAT was selected because it is a standardised test for

the Greek population and has been used extensively in research assessing creativity (Lee & Huggins, 2014; Sternberg, 2003). The standardised RAT test for the Greek population (RAT – Greek) (consists of ten questions. Each RAT question requires the participant to provide a solution word that is related to three cue words presented in the question (Koromvokis & Kalaitzidis, 2014; Alexopoulos & Kalaitzidis, 2004). The questions are designed so that the solution word is not a strong associate to any cue word. Thus, each possible solution requires that the individual search through long-term memory to find unusual or infrequent associations. For example, the participant is presented with the cue words (stimulus) "age, mile and sand". They must discover a common associate for each word, for example, "stone" (stone age, milestone and sandstone).

In regard to the immediate free recall tasks, previously applied methods were replicated (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015; Larigauderie, Michaud & Vicente, 2011; Campoy & Baddeley, 2008; Martin, 2005; Haarmann & Usher, 2001; Walker & Hulme, 1999; Poirier & Saint-Aubin, 1995). The first immediate free recall task involved 14 sets of semantically similar items, each set consisting of eight words. The second immediate free recall task contained another 14 sets of semantically dissimilar items, each set consisting of eight words. Both tasks were presented in fixed time to the participants. After the presentation of each set, the participant was asked to recall as many words as possible in any order.

The rationale behind the present experiment is based on the hypothesis that immediate free recall performance is facilitated more by semantic strategies than phonological (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012). Thus, in the implemented free recall task containing semantically similar items the easily accessed common semantic ground of the items is instantly available, dictating the elaboration of a semantic strategy. The employment of phonological strategies is supressed in favour of more economic solutions (Takeuchi, et al., 2011). A solution is considered economic when there is minimum demand for working memory capacity and resources as well as the required processing or recall time is significantly reduced (Tse, 2009; Conway, Cowan, Bunting, Therriault & Minkoff, 2002). In contrast, in the free recall task containing semantically dissimilar items, there was no obvious available solution to the problematic situation other than the phonological properties of the presented stimuli. In such a situation alternative strategies need to be used in order to achieve efficient performance. The most obvious solution is a semantic strategy, that is,

searching for remote associations between the items. Individuals with sufficient creative abilities here demonstrate significant advantage due to their thinking strategies and, more specifically, their ability to activate and retrieve remote associations.

The main hypothesis of the study, that creative individuals employ creative strategies during specific working memory processing, was tested using three separate methods in terms of analysis of the collected data. Two of these methods tested the hypothesis directly while the third tested it indirectly. These methods are outlined in sections 5.1 and 6.5.1.1 below. Additional analyses were carried out in order to investigate two general tendencies observed in the literature: the difference in performance between lists containing semantically similar items and lists containing semantically dissimilar items, and the correlation between working memory performance in lists containing semantically similar items and creativity performance. All three methods testing the main hypothesis revealed similar results allowing valid interpretations. The results indicate that creative individuals are able to employ different and controlled strategies in working memory processing according to the special characteristics of the referent task. In particular, creative individuals employ semantic strategies in demanding recall tasks, whereas less creative individuals fail to adapt semantic strategies. However, in less demanding tasks the implementation of automatic strategies is actually more benefitial, while the employment of creative strategies comes at a cost.

1.2 Overview of the thesis

"Chapter 2" offers and overview of dominant models and theories of working memory including Baddeley's multicomponent model (Baddeley, 2012), Cowan's model (2000), the Reconstruction and Retrieval based Hypotheses (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015) and the Feature Model (Neath & Nairne, 1995). The effect of phonological and semantic factors on working memory are also addressed. The semantic similarity effect is discussed along with analysis of the significant studies investigating the phenomenon. Finally, the strategies used in verbal encoding are investigated in conjuction with the semantic similarity effect.

"Chapter 3" provides an overview of research on creativity and the underlying cognitive mechanisms and processes of creative thinking and production: divergent thinking, convergent thinking and associative processing. In particular, this chapter highlights the role of associative processing in terms of creative thinking.

In “Chapter 4” all studies investigating the relationship between creativity and working memory are discussed and linked to the present study.

“Chapter 5” attempts to address the limitations of research in directly examining how creativity and creative strategies are related to the strategies incorporated in working memory processes. The overall methodological framework of the study is also presented in this chapter, along with the rationale, research questions, hypothesis, design, materials and the procedure followed.

“Chapter 6” presents the results of the statistical analyses in detail while Chapter 7, offers an anlysis of the results of the study. It is in this chapter that the theoretical as well as methodological implications of the findings are addressed. Finally, the limitations of the present study are noted and further research is proposed.

2. Working memory

2.1 Terminology

Working memory is an essential component for human higher order cognitive activities. Working memory is defined as an online cognitive process through which the learner acquires and processes new information (Baddeley & Logie, 2005; Cowan, 1999). Working memory also allows an individual to hold in their mind the knowledge that is relevant to solving a particular problem (Dietrich, 2014). Furthermore, working memory is the limited capacity storage system involved in the maintenance and manipulation of information over a short period of time (Baddeley, 2003). It is a functionally important system for the facilitation/processing of a wide range of cognitive activities such as reasoning, learning and comprehension (Baddeley, 2003). According to Engle and Kane (2003), working memory is a system of: (a) short-term "stores", assisted by long-term memory traces in a variety of representational formats active above a threshold; (b) rehearsal processes and strategies for achieving and maintaining that activation; and (c) executive attention. Baddeley's (2012) multicomponent model, which is the most widely accepted model, note that working memory is composed of the following four subcomponents: the central executive, the phonological loop, the visuo-spatial sketchpad and the episodic buffer.

The terms "working memory" and "Short-term Memory" were used interchangeably for some time. However, the introduction of more efficient explanations of the phenomenon has led to the elaboration of more accurate terminology for "working memory". Thus, in more recent research the two terms are interpreted as referring to different things. Further, the term "Short-term Memory" is now not broadly used to refer to the phenomenon (Baddeley, 2007). Because the terms "working memory" and "Short-term Memory" were previously used interchangeably they both appear interchangeably in the bibliography to this thesis. In recent research literature, the term "Short-term Memory" continues to be used to describe tasks in which the immediate recall of small amounts of information is required. On the other hand, the term "working memory" is used to refer to a broader system typically involving attentional control and allowing the manipulation, reconstruction and evaluation of information held in short-term memory storage. However, many studies that focus explicitly on short-term storage "continue to use the term 'Short-term Memory' to refer both to tasks and to the theoretically assumed underlying processes,

relying on the text context to make clear whether they refer to the task or the system" (Baddeley, 2012).

2.2 Historical review of research into "working memory" and "Short-term Memory"

The initial discrimination between "memory/long-term memory" and "working memory" or "Short-term Memory" was the first breakthrough in terms of research on cognition and memory. William James (1890) proposed a distinction between temporary primary memory, described as "the trailing edge of consciousness", and the more durable/long lasting secondary memory. By the middle of the twentieth century the dominant theoretical view of experimental psychology was the assumption of a single memory system in which learning was achieved by the formation of cognitive associations while memory loss, or forgetting, was due to interference between competing association nodes. In 1949, Donald Hebb reiterated the theory of two components of memory. He assumed that there are two types of memory, short-term memory, which is based on temporary electrical activity in the neural network of the brain and long-term memory which is supported by more durable neurochemical changes. This theoretical position was later supported by Brown (1958), in the United Kingdom, and Peterson and Peterson (1959) in the United States of America. In all of these theoretical and experimental approaches, the scholars observed a rapid memory loss over a matter of seconds for even a small amount of information when rehearsal was prevented or selectively blocked. However, because the rehearsal prevention experimental task did not involve material that was similar at any mean to the items being recalled, the classic similarity interference theory was questioned and eventually ruled out. The outcome was therefore the assumption of the existence of a memory trace that fades rapidly over time.

The most accepted model of working memory theory is Baddeley's (1974; 1993; 2012) model. This multicomponent working memory model assumes a four-component system, comprising (1) an attentional controller, the central executive, and three temporary storage systems, namely (2) the visuo-spatial sketchpad, (3) the phonological loop, and (4) a more general integrated storage and processing system the episodic buffer. It is assumed that the three systems (the central executive, the visuo-spatial sketchpad and the phonological loop) are limited in capacity, although the nature of their limitations is different. Initially, it was proposed that the central executive system has a purely attentional role and that it is incapable of storage. However, later

experiments and logical reasoning have highlighted the need for additional storage for more complex cognitive functions. This realisation has led to understanding of the fractionate nature of the central executive system as an alliance of separate attentional control processes. Problems with this concept were solved by the elaboration of the episodic buffer system. This is the spot where it is assumed the creative processes are established and operate. In particular, the episodic buffer system is assumed to form an interface system between the three working memory subsystems and long-term memory. It serves as a binding mechanism that allows perceptual information, information from the working memory subsystems and long-term memory, to be integrated into a limited number of episodes. In other words it is the interface between a number of codes (visual, verbal, perceptual information/stimuli and long-term memory representations).

2.3 Fundamental theories of working memory

2.3.1 Baddeley's multicomponent model of working memory

Baddeley's work on working memory has contributed on the abandonment of the assumption that working memory is comprised of a single unitary store system. The concept of a single unitary store system saw memory identified as a unified process without distinguishing differences between working/short-term memory and long-term memory. Initially, Baddeley and Hitch proposed a clear distinction between working/short-term memory and long-term memory. Furthermore, they defined working memory as a three component system (shown in Figure 1). They split attentional control from temporary storage, which previous literature indicated as reliant on separate verbal and visuo-spatial short-term memory. Temporary storage was thus divided into a "phonological loop", emphasising storage rather than rehearsal of verbal information, and the "visuo-spatial sketchpad". This also left open the issue of whether the "visuo-spatial sketchpad" was mainly visual, spatial or both. The central controller of the whole system was labelled as the "central executive".

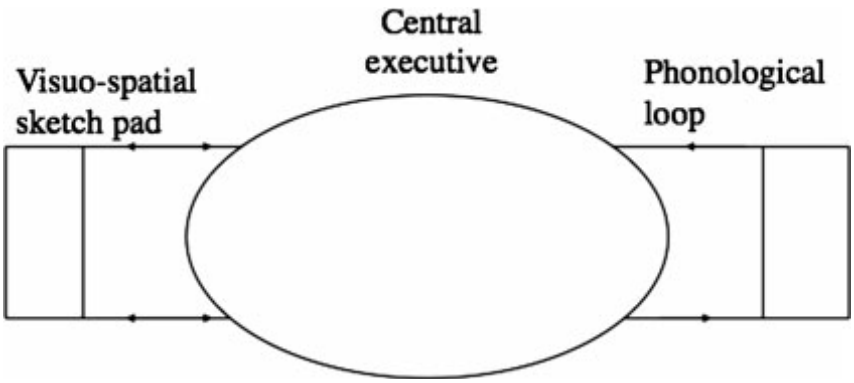


Figure 1. The original Baddeley & Hitch (1974, p. 51) working memory model.

The "phonological loop" is a relatively modular system comprising a brief store together with the means of maintaining information by vocal or subvocal rehearsal. In terms of the "visuo-spatial sketchpad", its rehearsal processes or contribution is uncertain. It has been suggested that there is a distinction between a "visual cache", a temporary visual store, and a spatial manipulation and rehearsal system, the "inner scribe", as a means of determining the nature of rehearsal in the sketchpad (Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996). It is further proposed that the "central executive" operates in two rather separate ways. One is based on crystalised habits or schemata, demanding little attentional control. An example of this might be the activity of driving a well-learned route to your office. This source of control can be overridden by the second process, the supervisory attentional system, which responds to situations that are not capable of being handled by the crystalised processes. For example, coping with the closure of a road on your normal route and therefore the need to process an alternative route. However, this division of the central executive system leaves unexplained data in the literature, as the main notion of central executive is purely attentional executive.

Extensive work on individual differences in working memory has revealed a correlation between measures termed "working memory span" and capacity for prose comprehension. Related studies required participants to read out a sequence of sentences and then recall the final word of each sentence. This and similar tests that require the combination of temporary storage and processing have proved enormously successful in predicting performance in terms of cognitive tasks. Such tasks range from comprehension to complex reasoning and from learning a programming language to resisting distraction. The results have caused a necessary update and restructuring of the scaffolding of the original model.

The main idea was that the model could not be based only on the limited capacities of the visuo-spatial and phonological subsystems. Therefore, a fourth component was added, the episodic buffer (Baddeley, 2000a), creating a more effective multicomponent model (illustrated in Figures 2 and 3). Generally, the updated multicomponent model allows incorporation into the working memory representations from long-term memory. The episodic buffer is assumed to hold integrated episodes or chunks in a multidimensional code. Its main function is to operate as a buffer store, not only between the different components of working memory — phonological loop, visuo-spatial sketchpad and central executive — but also as a connection between working memory components and long-term memory operations and representations. It holds multidimensional representations, but it has a limited capacity with regard to incorporating Cowan's assumptions of a capacity of four chunks.

Baddeley also offers a significant clarification of a consciousness process:

> I made the further assumption that retrieval from the buffer occurred through conscious awareness, providing a link with our earlier research on the vividness of visual and auditory imagery (Baddeley, 2012, p. 15).

Consciousness serves as a mechanism for binding stimulus into perceived representations. At the theoretical dimension, the updated multicomponent model of Baddeley (2012) can be incorporated as a mediation between the two main models of working memory outlined by Baddeley and Cowan:

> At a theoretical level it formed a bridge between our own bottom-up approach based on attempting to understand the peripheral systems first, and the more top-down approaches predominant in North America, which were more concerned with analyzing the executive and attentional aspects of working memory (Baddeley, 2012, p. 16).

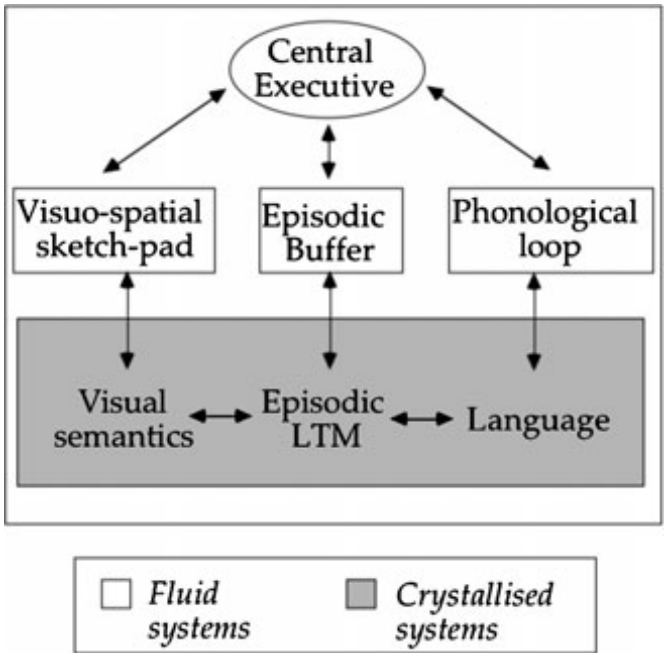


Figure 2. The model following the introduction of a fourth component, the episodic buffer, a system for integrating information from a range of sources into a multidimensional code (Baddeley, 2000a, p. 419).

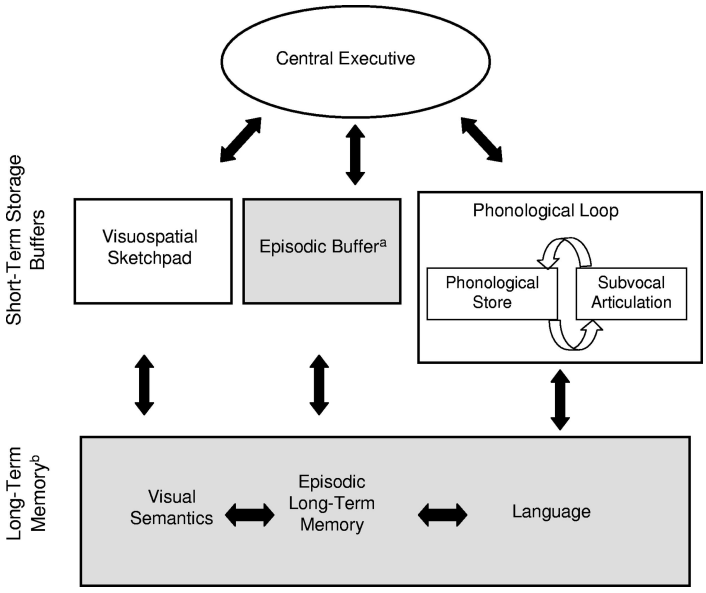


Figure 3. The multicomponent model of working memory. From "Is Working Memory Still Working?" by A. D. Baddeley, 2001, *American Psychologist*, *56*, p. 858. Copyright 2001 by the American Psychological Association. Boxes in gray represent additions from the original model proposed by Baddeley and Hitch (1974). Addition of the episodic buffer is from Baddeley (2000). Discussion of interactions with long-term memory is from Baddeley (2001).

2.3.2 Cowan's approach to working memory

A similar model to Baddeley's multicomponent model is offered by Cowan (2000). Even though the two models may appear completely different they actually differ only in terms of the adopted terminology and areas of research focus (Baddeley, 2012). Cowan (2000) concentrates on the link between the central executive notion and the episodic buffer. Cowan refers to the material on which his system works as "activated long-term memory" but does not treat this as providing an adequate explanation. He accepts the need for a more detailed analysis of the processes operating beyond attentional focus, as reflected in his extensive and influential work on verbal short-term memory. He sees the necessity of the operation of the episodic buffer. In particular, Cowan (2000; 1999) formulates a model of working memory that takes into account semantic contributions to verbal short-term memory. This model includes the phonological loop as a component of a verbal short-term storage system. Generally, the model underpins the importance of activation and attention (Figure 4). Cowan also postulates that lexical and semantic codes play an active role in the retention process. Activation of long-term memory representations of the material to be maintained in short-term memory is a key mechanism for short-term storage, with activated long-term memory providing a representational basis for short-term memory maintenance. Cowan (2000) further proposes that focusing attention upon the information to be maintained maximises activation of the relevant codes in long-term memory.

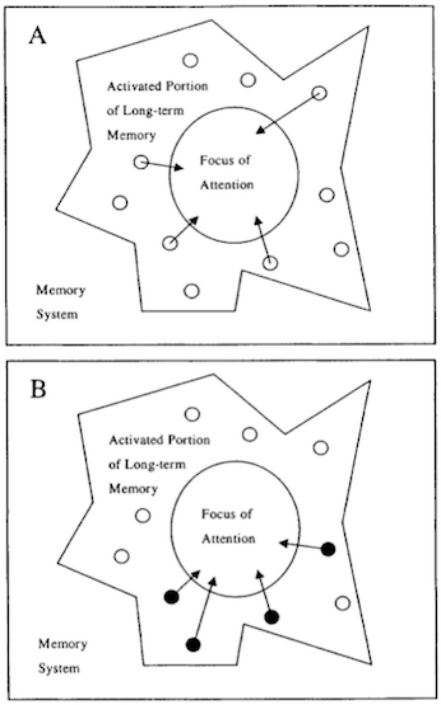


Figure 4. Illustration of the processing in (*A*) whole report procedures and (*B*) partial report procedures according to the nested processes framework suggested by Cowan (1988; 1995). In each figure, information is elevated from activated storage (jagged lines) to the limited capacity store, which is the focus of attention (large circle), until the latter is full. Small circles represent items in the array, and those with arrows enter the focus of attention. With partial report (*B*), the cued items (filled circles) preferentially enter the limited-capacity focus of attention. From Cowan, N. (2000, p. 127). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, *24*, 87–185.

2.3.3 The reconstruction and retrieval based hypotheses

The reconstruction and retrieval based hypotheses consist of a group of models that were developed mainly in order to account for the observable effects of long-term memory factors on immediate serial and item recall tasks. The proposed models assume a mechanism linked to the reconstruction process. According to these proposals, the presentation of a list sets up phonological representations of the items to-be-remembered (Poirie, Saint-Aubin, Mair, Tehan & Tolan, 2015). At recall, these representations are likely to be degraded because of either decay or interference. The degraded phonological representations must then undergo a reconstruction process before being output as a response (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). The reconstruction process is be based on the long-term phonological knowledge of the to-be-recalled items. The reconstruction hypothesis provides an efficient explanation for semantic unrelated items, the non words and the low frequency effects, because the long-term memory representations of the to-be-recalled items are more difficult to

access, which in turn decreases the probability of a successful reconstruction, and consequently of a correct response.

The reconstruction and retrieval based hypotheses have been developed and empowered by the work of Saint-Aubin and Poirier (Poirier M., Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999b; Poirier & Saint-Aubin, 1995). They have taken into consideration the separate effects of item and order of information. For example, if the degraded trace of a word from the to-be-remembered list of words has characteristics shared with other words, then the probability of erroneously recalling another item within the list is high. By the same analog,y the probability of order errors is also likely to be higher when list items share more phonological features, or when the phonological trace has lost many unique features due to degradation (Saint-Aubin, Ouellette & Poirier, 2005). Consequently, the probability of order errors can be said to be higher when list items share more phonological features or when the phonological trace has lost many unique features due to degradation.

The probability of an error occurrence is mainly attributed to the difficulty in accessing the long-term memory representation of the to-be-remembered word or the effect of articulatory suppression. Saint-Aubin and Poirier's account assumes better word recall for semantically similar items because the semantic category shared by the to-be-remembered word enhances the probability of accessing the relevant long-term memory representation, perhaps by reducing the pool of recall candidate items. Furthermore, the semantic similarity effect is expected not to have any significant effect on order recall. In terms of the semantic similarity effect, it is expected that the same mechanism is applied for frequency effect. The same could also be predicted for non word effect when applied to item recall but not for order recall, assuming a higher proportion of order errors anticipated for words than for non words.

2.3.4 The feature model

A relevant approach to the reconstruction and retrieval based hypotheses is proposed by Neath and Nairne (1995). According to the model, list items are represented in both primary and secondary memory as a sequence of features that can have differences or similarities in various dimensions, such as phonological and semantic. As in the case of the reconstruction and retrieval based hypotheses, degradation can only occur in primary memory, and recall is implemented by connecting the relevant intact item in secondary memory with the degraded trace from primary memory. Therefore, more

complex features of words than of non words, and of high rather than of low frequency words, can lead to an advantage in item recall. However, the model cannot efficiently explain some semantic similarity effects in serial recall as it predicts that semantic similarity is detrimental to order information recall. Generally, it is difficult to evaluate how the feature model could account for the influence of long-term memory factors on item and order information (Baddeley, 2012).

2.4 The effect of phonological, non-phonological and semantic factors on working memory/verbal short-term memory

Studies of working memory and more specifically verbal short-term memory mainly involve immediate item recall or immediate serial recall of words (for example, semantically similar or dissimilar words or non words). Immediate free recall requires participants to study a list of items. They are then prompted to recall the items in any order. In contrast to immediate free recall, the immediate serial recall paradigm refers to the type of studies where participants are asked to recall the presented items in their correct order rather than the order that comes to mind at the time of testing, that is, randomly (Baddeley, 2007). Furthermore, each item has to be recalled in its exact serial position as this is evaluated according to the presented serial position of the stimuli. In particular, each recalled item in order to be considered as a correct reaction has to be recalled in its exact serial position, meaning that the item and the order information are not differentiated (Saint-Aubin & Poirier, 1999).

2.4.1 The effect of phonological factors on working memory

Initial attempts to study the structure and processes of working memory or verbal short-term memory in relation to verbal information found some significant results. These studies effectively contributed to the development of the aforementioned scientific area. However, the interpretation of the findings and the applied methodology of these intital attempts does not allow for extensive and exclusive investigation of all the relevant factors (Saint-Aubin, Ouellette & Poirier, 2005). In summary, the findings indicate that participants' performance in relevant tasks of immediate recall is affected by the phonological properties of the presented stimuli. These studies concentrated on the phonological factors that might affect performance in immediate recall. Therefore, specific effects were investigated. The data of those experiments was interpreted as a proof for a specific orientation. According to this view the verbal information is encoded and processed only in term of verbal short-term memory and the recall of this information relies mainly on phonological representations of the presented verbal

stimuli. The main investigated effects are the phonological similarity effect (Baddeley, 2007; Baddeley, Lewis & Vallar, 1984; Besner & Davelaar, 1982; Baddeley, 1966; Conrad & Hull, 1964), the stimulus/word length effect (Baddeley, 2012; Baddeley, Thomson & Buchanan, 1975), the effect of articulatory suppression (Klatte, Lachmann, Schlittmeier & Hellbruck, 2010; Baddeley, Hitch & Allen, 2009; Baddeley & Larsen, 2007; Jones, Hughes & Macken, 2006; Murray, 1967;), the irrelevant speech effect (Klatte, Lachmann, Schlittmeier & Hellbruck, 2010; Jones, Macken & Mosdell, 1997; Miles, Jones & Madden, 1991; Salamé & Baddeley, 1982; Colle & Welsh, 1976), the interaction between articulatory suppression and similarity, irrelevant speech and word length (Baddeley, 2012) and finally the recency and primacy effects (Bauml & Hartinger, 2002; Anderson, Green & McCulloch, 2000; Smith & Hunt, 2000; Roediger & Schmidt, 1980) as well as the temporal clustering effect (Kahana, 1996).

In particular, the word length effect indicates that participants' performance systematically declines with the length of the presented words. One of the main experiments studying the word length effect is performed by Baddeley, Thomson and Buchanan (1975). This experiment tested the immediate recall of words ranging in length from one syllable to five syllables. The main assumption was that vocal or subvocal rehearsal is present in short-term memory. Longer words require more time in rehearsing, that is decoding and processing, and hence this process allows more time for trace decay. Increased decay due to the increase of articulation time decreases performance in recalling words. The results and their interpretation of the study performed by Baddeley, Thomson and Buchanan (1975) indicate that participants were able to remember as many words as they could articulate in two seconds. Baddeley, Thomson and Buchanan (1975) also propose that decay is possible during spoken recall. Thus, longer words result in poorer recall performance because they require more time to recall, leading to more forgetting (Baddeley, Chincotta, Stafford & Turk, 2002).

In summary, Baddeley, Thomson and Buchanan argue that decay is mainly time-based. However, Baddeley later comments with relation to this study:

> the general hypothesis of a phonological loop will function equally well with either a decay or interference interpretation of short-term forgetting, illustrating the value of combining a broad theoretical map while leaving more detailed modeling to be decided by further experimentation (2007, pp. 43).

Baddeley provides evidence to support this view in an earlier study (Baddeley, 1984). Data connected with this study indicates that the tendency for long words to be

less well remembered than short words is abolished by articulatory suppression. However, Jacquemot, Dupoux and Bachoud-Levi (2011) provide data indicating that in experiments that include word length effect manipulations, the comprehension and word production systems are both unimpaired, and that the typical mechanisms engaged in phonological input and phonological output are intact. Additionally, it has been observed that there is also an influence with regard to lexico-semantic factors (Romani, Galluzzi & Olson, 2005; Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997; Brown & Hulme, 1995). Longer words have an advantage over shorter words. They offer more information from which to attempt reconstruction (redintegration) and fewer lexical competitors. If a part of the to-be-remembered word decays, it can be be reconstructed, for example, "telescope" from "tele...pe". However, in a shorter word the loss is more difficult to retrieve.

> In these models, the word-length effect results from the coupled effect of trace decay and of lexico-semantic influence and there is no need of subvocal rehearsal to account for it (Jacquemot, Dupoux & Bachoud-Levi, 2011, p. 489).

The phonological similarity effect refers to the effect of phonologically similar words or letters in immediate recall (Baddeley, 1966; 2007; Baddeley, Lewis & Vallar, 1984; Besner & Davelaar, 1982; Conrad & Hull, 1964). The basis for the observation of this effect is the assumption that there is a link between speech coding and short-term memory. The phenomenon generally indicates that phonologically similar items, words or letters, result in poorer immediate memory performance as tested by recall (Baddeley, 2007). Conrad and Hull (1964), in their experiment, show that recall for sequences of letters is impaired when phonologically similar letters are incorporated. This observation was established using error analysis, indicating that the errors were similar to the previously presented correct items. Baddeley (1966) demonstrates a similar effect for words. He compares similar and dissimilar words. The results indicate that immediate recall for phonological similar words is less successful than for phonological dissimilar words.

The interpretation and explanation of the data implies that short-term memory is based on an acoustic store. However, further study of the phenomenon has since indicated that short-term memory actually relies on subvocal rehearsal and the encoding is articulatory and not acoustic. Baddeley, Lewis & Vallar (1984) report that the phonological similarity effect is constant despite the use of articulatory suspension experimentation. Besner and Davelaar (1982) also argue that a severe impairment

occurs even when the rate of suppression increases. This is due to the involvement of the central executive when maximum articulation is required. Moreover, Baddeley (2012) reports that the phonological similarity effect is present even when the similar items are sandwiched between dissimilar items. This particular observation led Baddeley to change his original approach with regard to the importance of the phonological loop (Baddeley, 1968). Additionally, based on the findings of his study, he notes that the phonological similarity effect disappears with long sequences of lengths, indicating that when the phonological loop is no longer able to cope with the requirements of the requested activity the subjects then rely on other strategies or capacities (Baddeley, 2000). Thus, he incorporates other dimensions within the original model. He includes the relationship between short-term memory and long-term memory and more specifically, the episodic buffer. This approach is supported by other studies as well. As already been noted above, Jacquemot, Dupoux and Bachoud-Levi (2011) support the idea that lexico-semantic factors influence the phonological similarity effect and that these factors overcome any disruption caused by the effect.

The study of the articulatory suppression effect is strongly related to the phonological similarity effect and the word length effect. As already discussed, word length effect is dependent on subvocalisation. According to this perspective, recall performance should be affected when subvocalisation is prevented because the articulatory loop for maintaining items in memory is suppressed. The typical prevention experimentation consists of repetition by the participant of a single irrelevant sound or word, such as “and”. Murray (1967), as well as Baddeley, Hitch and Allen (1974), demonstrate in their experiments that the articulatory suppression effect is present irrespective of the presence of the word length effect. In other words, the ratio of impaired performance due to the subvocalisation prevention is the same in short and long words. It has also been observed (Baddeley, Lewis & Vallar, 1984) that the articulatory suppression effect eliminates the phonological similarity effect. However, this observation is only possible in experiments where the items are presented in verbal form. When the items are presented in written form, the phonological similarity effect is present even with articulatory suppression. The proposed explanation claims that oral items access the phonological store automatically whereas written materials have to be firstly subvocalised. In other words, during the rehearsal process the visually presented items have to be transformed into a phonological code prior to entry into the phonological store. On the other hand, the verbally presented items have direct access to

the phonological store without requiring a rehearsal process (Klatte, Lachmann, Schlittmeier & Hellbruck, 2010).

This explanation of the phenomenon is criticised by Jones, Hughes & Macken (2006). However, Baddeley and Larsen (2007), in turn, question this criticism. Furthermore, Jacquemot, Dupoux and Bachoud-Levi (2011), relying on data from their study, indicate that the effect of lexico-semantic factors is more influential than the effect of the number of phonological features and the articulatory suspension effect, leading to the abolition of the word length effect and the articulatory suspension effect. Furthermore, in studies containing articulatory suppression experiments, it has been proven that even though the word length effect is diminished, other familiarity based effects (for example, word frequency, lexicality effect) are nevertheless present (Woodward, Macken & Jones, 2008; Thorn, Gathercole & Frankish, 2002). Also, Goh and Goh (2006) report findings indicating that the word length effect is sharply attenuated when all the within-list words are from the same semantic category. These findings minimise the importance of non semantic factors in working memory. These findings indicate the absence of differences in articulatory processes, and suggest the engagement and significance of long-term memory processes on verbal short-term memory operation. Moreover, under articulatory suppression, the word length effect is diminished while the lexicality effect is not (Besner & Davelaaar, 1982). The revelation that lexicality and other familiarity based effects (for example, word frequency and bilingual language familiarity effects) are apparent even in the absence of differences in articulatory duration indicates that factors such as long-term memory support via redintegration, rather than via articulatory fluency, are in operation (Thorn & Gathercole, 2001; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Hulme, Maughan & Brown, 1991).

The irrelevant speech effect, or the irrelevant sound effect (Klatte, Lachmann, Schlittmeier & Hellbruck, 2010; Jones, Macken & Mosdell, 1997; Miles, Jones & Madden, 1991; Salamé & Baddeley, 1982; Colle & Welsh, 1976), is mainly an experimental manipulation. The phenomenon refers to the degradation of participants' performance in immediate serial or free recall experiments when irrelevant (or even sometimes relevant) background sounds are presented during the trials and alongside the target stimulus. The target stimulus consists mainly of sequences of visually presented verbal items such as digits, syllables or words. The irrelevant speech effect or the irrelevant sound effect has been found to be significant for background speech

(Klatte, Lachmann, Schlittmeier & Hellbruck, 2010). However, there is no significant effect on prose spoken in an unfamilliar foreign language to participants (Colle & Welsh, 1976). Significant effects were also reported for artificial language sounds such as simple sounds (Elliott, 2002; Divin, Coyle & James, 2001) as well as sounds produced by instruments (Schlittmeier, Hellbruck & Klatte, 2008). Although the recall performance is specifically impaired by irrelevant background sounds only if the sounds are interchangeable in volume or characteristics. Steady sounds, such as repetitions of single syllables or tones, do not cause significant or indeed any disruption to immediate recall performance (Beaman, 2005).

The interaction between articulatory suppression and similarity, irrelevant speech and word length (Baddeley, 1986) should be considered as very important because it reveals significant information about the structure of short-term memory. Further, when the irrelevant speech effect is removed with articulatory manipulation suppression, indicates that the irrelevant speech effect operates via the phonological store. The presence of suppression forces are shown to be not utilising the phonological store and therefore the irrelevant speech effect does not cause any degradation (Baddeley, 2012). Salamé & Baddeley (1990) argue that the irrelevant speech effect disappears when the factors of phonologically similar as well as non phonologically similar stimuli are enforced. In contrary to the proposal pur forward by Colle (1980), these results indicate that when the phonological loop is no longer able to cope with the requirements of the requested activity then the subjects rely on other strategies or capacities (Baddeley, 2000). Overall, it can therefore be assumed that the irrelevant speech effect and the similarity effect, when combined, produce additive effects. This indicates that the assumption of a unique phonological loop approach for the explanation of short-term memory is not efficient. Furthermore, Jacquemot, Dupoux and Bachoud-Levi's (2011) study into patients with low phonological memory capacities reveals that working memory in these patients can rely on the lexico-semantic level rather than the phonological to store and recall provided items. This is available through the activation of the lexico-semantic level minimising the effects of articulatory suppression, phonological similarity, irrelevant speech and word length.

Other interpretations for the irrelevant speech effect have been proposed. Initially, on the base of the phonological loop view, it was assumed that irrelevant speech or sounds have obligatory access to the phonological store, where they interrupt the representation of the memory list (Baddeley, Lewis & Vallar, 1984). However,

Baddeley (2012) later contradicts this proposal and suggests that there are additional factors affecting performance in irrelevant speech experiments. In particular, Baddeley (2012, p. 9) states that:

> Unfortunately, our initial hypothesis came to be regarded as central to Working Memory, despite our subsequent withdrawal, a salutary lesson in premature theorizing... [and]... This proved to be something of an embarrassment when it was clearly demonstrated that irrelevant items that were phonemically similar to the remembered sequence were no more disruptive than dissimilar items.

An alternative explanation is proposed by Jones, Hughes and Macken (2006) on the basis of the object-oriented episodic record (O-OER) model. According to this view, an item/sound consists of different elements and is automatically represented in short-term memory as a sequence of objects. The irrelevant speech creates links with the to-be-learned list of items. Therefore, the deliberate rehearsal of the target list is interrupted, creating the effect.

Finally, Neath (2000) proposes another explanation for the irrelevant speech effect on short-term memory by introducing the Feauter Model. The main idea of the model is that short-term memory traces consist of two types of feautures; modality dependent features and modality independent features. The modality dependent features are considered the raw, physical characteristics of the stimuli. The modality independent features represent abstract aspects independent of modality (Klatte, Lachmann, Schlittmeier & Hellbruck, 2010). Identification and categorisation are typical processes of the second type. According to the Feauter Model, the irrelevant speech effect interupts the modality independent features. This may happen when modality-independent features of the list items are replaced by modality-independent features of irrelevant speech. However, this can only be observed with speech as irrelevant sound but not in the case of non speech sounds. The irrelevant speech effect thus causes detrimental effect due to attentional distraction (Neath, 2000). It is important to stress that the effect of semantics does not cause any disruption in relation to irrelevant speech stimulus (Klatte, Lachmann, Schlittmeier & Hellbruck, 2010) but rather disruption is caused by factors such as the frequency of the words (Buchner, Mehl, Rothermund & Wentura, 2006).

2.4.2 The effect of multiple factors on working memory

Previous studies have revealed that there are other relevant factors related to working memory and, more generally, to immediate free recall experiments. A well investigated

phenomenon is the recency or primacy effect. The main assumption is that an item's recall probability declines in accordance with its position on the presented list of words (Bauml & Hartinger, 2002). In other words, there is a tendency for subjects to demonstrate better recall of words that appear at the ends of presented lists of words, in contrast to words from the beginnings of the same lists (Deese & Kaufman, 1957; Murdock, 1962). The phenomenon is mainly interpreted as a forgetting process during the act of recall. This interpretation partially supports the idea of a mainly phonological working memory and it has been proven to not be based on the strengthening of the practised words (Bauml & Hartinger, 2002), making this way a clear distiction between practice and presentation. Evidence indicates that whereas repeated retrieval of the lists can cause forgetting, repeated presentation of the lists does not (Anderson, Bjork & Bjork, 2000).

Recency and primacy effects have been also studied in relation to the semantic similarity effect (Bauml & Hartinger, 2002; Anderson, Green & McCulloch, 2000; Smith & Hunt, 2000; Roediger & Schmidt, 1980). Haarmann and Usher (2001), for example, found evidence of semantic information maintenance in short-term memory in relation to the recency effect. In their experiment, participants encoded lists of words and then were asked to take part in a free-recall test. Each list consisted of related word pairs either adjacent or separated by other items. The collected data provided clear evidence that recency effects exist and that semantic representations can be activated although this effect is gradually lost as time passes.

Another related phenomenon is referred to as temporal clustering: participants have a tendency to better recall words that occupy neighbouring positions in the studied lists in immediate free recall experiments (Kahana, 1996). This effect has mainly been studied under conditions of free immediate recall and not serial recall. Furthermore, it was one of the main reasons behind the move away from the study of paired associate learning and serial recall in the nineteen fifties and early sixties, and the move towards to the study of free recall in the sixties. The necessity of studying the importance of inter-item similarity and context-to-item associations as the basis for retrieval was the main reason for this experimental shift. Specifically, Asch and Ebenholz (1962, p. 19) report that "the order in which items were produced in free recall (which registered the course of acquisition) did not correspond notably to the order of earlier experience". Generally, the related data reveals that the serial recall position slot indicates a minor primacy effect, a large recency effect, and a moderate middle region effect

(alternatively referred as asymptote). A correlation analysis of the recalled position reveals a pattern. The alternative indicates that words from the recency position are recalled first and items from asymptote are recalled last. The words from the moderate middle region (asymptotic) in the presentation list are reported at the asymptote position in the output position list. Further, Kahana (1996, p. 105) presents three main findings:

> First, the probability of successive recall from adjacent input positions is about three times higher than the probability of successive recall from remote input positions. Second, the probability of adjacent forward recalls is about twice that of adjacent backward recalls. This forward recall advantage is present at all output positions. Third, adjacency and asymmetry effects are observed for latency as well as accuracy measures.

However, serious concerns about the nature of subject-generated retrieval cues are also noted indicating that (Kahana, 1996, p. 104):

> Neither serial position curves nor mean output position curves provide us with useful information about the specific item-by-item contingencies in output order. The equivalence of recall probability and output position for asymptotic items (often assumed to be retrieved from long-term memory) has suggested that there are no consistent relations between input order and output order for these items. Rather, it is generally assumed that the retrieval of asymptotic items reflects a semantically and/or contextually guided search through long-term memory.

These theoretical and methodological concerns raise important questions regarding the tendency to explain verbal information encoding and recall on the basis of a sole verbal short-term memory.

2.4.3 The effect of non phonological and semantic factors on working memory

Inverstigations of the aforementioned effects has led to the initial assumption that verbal information is encoded and processed only on verbal short-term memory and the recall of this information relies mainly on the phonological representations of the presented verbal stimuli. However, recent research supports the idea that non phonological factors, alternatively referred to as psycholinguistic or semantic variables, participate equally in working memory or verbal short-term memory alongside the already presented phonological factors.

The idea that a variety of factors such as non phonological and semantic, alongside phonological factors, equally influence working memory or verbal short-term memory, is derived from and supported by observations of non phonological effects,

that is, linguistic properties of the words. This is alternatively referred to as the effect of semantic factors. Research into this area indicates significant and sizable phenomena. One indicative, but not exclusive effect, is the lexicality effect: participants demonstrate better recall of words than non words in immediate recall tasks (Majerus, van der Linden, Mulder, Meulemans & Peters, 2004; Gathercole, Pickering, Hall & Peaker, 2001; Turner, Henry & Smith, 2000; Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997; Hulme, Maughan & Brown, 1991; Besner & Davelaar, 1982; Roodenrys, Hulme, Alban, Ellis & Brown, 1994). Another relevant phenomenon is the frequency effect: participants have better recall of high-frequency words than low-frequency words in immediate recall tasks (Woodward, Macken & Jones, 2008; Roodenrys, Hulme, Lethbridge, Hinton & Nimmo, 2002; Grant et al., 1997; Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Gregg, Freedman & Smith, 1989). In addition, sequences of pseudo words constructed to conform to the phonotactic regularities of the participants' first language sustain better serial recall than those which do not (Majerus, van der Linden, Mulder, Meulemans & Peters, 2004; Roodenrys & Hinton, 2002; Gathercole, Frankish, Pickering & Peaker, 1999; Grant et al., 1997; van Bon & van der Pijl, 1997; Gathercole, 1995; Gathercole, Willis, Emslie & Baddeley, 1991). Further, in relation to first and second language recall it has been observed that there is a better recall performance for first versus second language material in second language learners and bilinguals (Thorn, Gathercole & Frankish, 2002; Chincotta & Hoosain, 1995; Service, 1992). The same effect is still observable after training. However, the recall does increase as a result of an increase of long-term memory engagement (Messer, Leseman, Boom & Mayo, 2010; Hulme, Maughan & Brown, 1991).

The aforementioned effects are referred to as non phonological effects because they are based on the linguistic properties of the words and not solely on the phonological properties of the items. However, they are also referred to as semantic effects. This distinction is made on the basis of the gravity of the semantic dimensions (Larigauderie, Michaud & Vicente, 2011). As a result, in this thesis the non phonological effects will be presented before effects that are characterised by significant and solid semantic variables. Interpretation of these effects will concentrate on the relationship between short-term and long-term memory. The interaction between short-term memory and long-term memory is an area that requires greater investigation. Experimental data derived from detailed studies illustrates the role of permanent representations in the functioning of verbal short-term memory, which has enabled the

emergence of new models. These models include explanations of effects other than the phonological ones, discussed above.

2.4.3.1 Lexicality effect

The lexicality effect has previously been investigated in many studies (Majerus, van der Linden, Mulder, Meulemans & Peters, 2004; Gathercole, Pickering, Hall & Peaker, 2001; Turner, Henry & Smith, 2000; Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Hulme, Maughan & Brown, 1991; Besner & Davelaar, 1982). The term, lexicality effect, mainly describes the observed tendency towards better recall performance for words than for non words. The effect is generally attributed to the contribution of long-term memory to working memory memory performance (Turner, Henry & Smith, 2000). It has been observed in serial recall and item recall experiments in both adults and children. The principal idea relies on the importance of the stored phonological representations for familiar words to support decaying or decayed traces in phonological short-term memory before a response is given (Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997). For unfamiliar words or pseudo words, no representation in long-term memory is available to support traces, and this results the poor performance of word recall. Saint-Aubin, Ouellette and Poirier (2005) report that the lexicality effect should affect order recall as well as typical free recall. Furthermore, in studies containing articulatory suppression experiments, it has been observed that even though the word length effect is diminished due to articulatory suppression, the lexicality effect has a sustainable effect on participants' recall performance (Woodward, Macken & Jones, 2008; Thorn, Gathercole & Frankish, 2002). This observation stresses the importance of long-term memory processes on verbal short-term memory. In other words, these findings indicate the importance of episodic buffer (Baddeley, 2012) or the existence of the semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011).

Two possible explanations have been suggested. Both of them indicate the importance of lexical, phonological and semantic knowledge on working memory. However, the main distinction between those two approaches appears to be in how the lexical knowledge supports working memory and, more specifically, verbal short-term memory (Gathercole, Frankish, Pickering & Peaker, 1999). According to the first approach lexical knowledge affects short-term storage through a "redintegration" process when retrieval of the presented information is performed. This is achieved by reconstructing the decaying traces of items stored in short-term memory. The

reconstruction is facilitated by the lexical representations in long-term memory (Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997; Hulme, Maughan & Brown, 1991). The second approach claims that the interaction between working memory memory and long-term memory is active and bidirectional. According to this theory the decay of item traces is prevented via recurrent feedforward–feedback activations. This process highlights the importance of the episodic buffer and the central executive system (Baddeley, 2012; Martin, 2005; Gathercole, Pickering, Hall & Peaker, 2001; Gathercole, Frankish, Pickering & Peaker, 1999).

2.4.3.2 The frequency effect

The frequency effect is described by the tendency of participants to more successfully recall high-frequency words than low-frequency words in immediate recall tasks, either serial or free (Woodward, Macken & Jones, 2008; Roodenrys, Hulme, Lethbridge, Hinton & Nimmo, 2002; Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Gregg, Freedman & Smith, 1989). In generally terms, long-term knowledge contributions to working memory are responsible for the immediate recall performance found in high frequency words when compared with low frequency words. The explanation of the word frequency effect is redintegration, the same as for the lexicality effect. Redintegration is the process of reconstruction in which representations in long-term memory are used to rebuild information from the short-term memory traces that have passively decayed.

This tendency is also observed in Williams syndrome, a rare neurodevelopmental disorder. Patients with Williams syndrome show more deficits related to language than other cognitive domains (Grant et al., 1997). The syndrome is related to long-term knowledge with respect to language. Grant et al. reveal that the effect of word frequency in immediate item recall is reduced in children with Williams syndrome in comparison with normally developing children. While both groups performed better in recalling high frequency words, the frequency effect was reduced in children with Williams syndrome. According to Grant et al. (1997), this pattern is explained on the basis of the collaboration between short-term memory and long-term memory. They suggest that:

> Williams syndrome individuals have relatively good phonology and vocabulary, but show abnormal patterns of performance on tasks such a s verbal fluency which require efficient access to semantic information stored in long-term memory (Grant et al., 1997, p. 84).

In accordance with this view Majerus, van der Linden, Mulder, Meulemans, and Peters (2004, p. 298) suggest that:

> the long-term memory influence does not seem to be related to differential item redintegration effects for high and low frequency words, but rather to higher inter-item lexicosemantic associations for high frequency words, as high and low frequency words are recalled at intermediate and identical levels when presented together in the same alternating list.

Furthermore, in studies containing articulatory suppression experiments, it has been proven that even though the word length effect is diminished, word frequency effect is present (Woodward, Macken & Jones, 2008; Thorn, Gathercole & Frankish, 2002). These findings indicating the absence of differences in articulatory processes suggest the engagement of long-term memory processes on working memory memory operation. In other words, these findings demonstrate the importance of the episodic buffer (Baddeley, 2012) or the existence of a semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011).

2.4.3.3 Phonotactic effect

Another closely related effect to the lexicality and word frequency effects is the phonotactic effect. According to this effect, sequences of non words constructed to conform to the phonotactic regularities of the participants' own language sustain better serial recall than those that do not (Majerus, van der Linden, Mulder, Meulemans & Peters, 2004; Roodenrys & Hinton, 2002; Gathercole, Frankish, Pickering & Peaker, 1999; Grant et al., 1997; van Bon & van der Pijl, 1997; Gathercole, 1995; Gathercole, Willis, Emslie & Baddeley, 1991).

One of the main studies of the phonotactic effect has been performed by Gathercole (1995). She observes that in experiments containing pseudowords, some sequences of non word letters appeared to be harder than others to recall. The non words that were easier to recall more accurately were the ones that most closely resembled English words. She tests this hypothesis by constructing two groups of non words on the basis of phonotactic frequency measures. Her findings indicate that those sequences closer to English (for example, stirple; blonterstaping) are recalled more accurately and more easily than non words containing less phonotactic characteristics (for example, kipser; perplisteronk). According to Gathercole (1995) the beneficial effect of phonotactic regularities in pseudo words is attributed to the activation of lexical representation in long-term memory, thus demonstrating that the phonotactic

effect is independent of articulatory rehearsal factors. This finding would have resulted an impaired performance in Williams syndrome patients (Grant et al., 1997), as they do not have access to long-term lexical knowledge and thus raises questions over the efficiency of the explanation. However, Grant et al. (1997) do not observe this tendency in their study.

Gathercole's (2005) approach requires the division of the phonological loop into separate storage and articulatory sections, while the pseudo word recall task might demand both of these. In contrast, only the articulatory output system might be based on language related knowledge, leaving the phonological store relatively language-independent. If the phonological store is dominated by earlier habits then new knowledge would be difficult to process as it would be affected by earlier knowledge. Although this could be true in the second level articulatory output stage. Baddeley (2000) instead proposes that linguistic knowledge could influence the phonological store through the episodic buffer. According to this approach the decay of item traces is prevented via recurrent feedforward–feedback activations. This process indicates the importance of the episodic buffer and the central executive system (Baddeley, 2012; Martin, 2005; Gathercole, Pickering, Hall & Peaker, 2001; Gathercole, Frankish, Pickering & Peaker, 1999). Other theoretical approaches consider that the interaction between working memory store and language representations are greater and language knowledge is operational during all working memory stages (Baddeley, 2000).

2.4.3.4 First and second language effect

It has previously been demonstrated that there are significant variations in serial and free recall for bilingual speakers. In relation to first and second languages, there appears to be better recall performance for the first versus the second language material in second language learners and bilinguals (Thorn, Gathercole & Frankish, 2002; Chincotta & Hoosain, 1995; Service, 1992). Initial attempts to interpret this effect were based on the original idea of rehearsal of verbal information. According to this interpretation, information that is decaying could be sustained in working memory by refreshing the relevant representation. The outcome could be obtained by sub vocal rehearsal (Baddeley, Lewis & Vallar, 1984).

However, this interpretation does not provide sufficient explanation for the phenomenon. The existence of a problematic interpretation on the basis of sub vocal rehearsal was apparent on specific experimental findings relating to manipulations that prevented sub vocal rehearsal. These findings revealed that bilinguals' language

familiarity effects and other familiarity based effects (for example, word frequency) were present in immediate serial and free recall experiments even in the absence of differences in articulatory duration. These results indicate that factors such as the reduced opportunity for decay at recall and long-term memory support via redintegration, rather than via articulatory fluency, are in operation (Thorn, Gathercole & Frankish, 2002; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Hulme, Maughan & Brown, 1991). Further research and reasonably more sufficient experiments have since provided a basis for alternative interpretations indicating that the first language advantage in second language learners and bilinguals in immediate serial and free recall experiments cannot exclusively be attributed to language specific differences (Baddeley, 2012).

An alternative proposal to the interpretation claiming that the phenomenon is based on the sub vocal rehearsal, explains the language familiarity effect on reduced opportunities for decay at recall. Experimental studies with monolingual participants reveal that there is a significant correlation between the immediate item and serial recall accuracy and the typical pronunciation time of the items by the participants (Cowan, Day, Saults, Keller, Johnson & Flores, 1992). This interpretation has been used to explain the language familiarity effect in second language learners and bilinguals. The articulation rate in the first language or the dominant language has a positive effect on the reduced trace decay. However, this interpretation is somewhat limited as analysis of serial recall data suggests that “the superior recall of first-language memory lists persists for first- and second- language memory stimuli of comparable articulatory duration” and “there has as yet been no direct investigation of whether output delay contributes to the language familiarity effect at all under conditions in which first and second language stimuli do differ in articulatory duration” (Thorn, Gathercole & Frankish, 2002, p. 1363).

Finally, a more reliable interpretation is based on the idea of redintegration. It is assumed that first language superiority is based on the differential availability of long-term knowledge in relation to the second language. The accuracy on immediate recall of a verbal stimulus is influenced by prior linguistic knowledge. According to Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart (1997) this is possible through the elaboration of the process of redintegration. According to this view permanent linguistic knowledge is elaborated to reconstruct degraded verbal information. This account can be used to explain the language familiarity effect in second language learners and

bilinguals (Chincotta & Hoosain, 1995). According to Thorn, Gathercole & Frankish (2002, p. 1365):

> By virtue of the differential level of familiarity that bilinguals have with their two languages, degraded traces of first language memory items will be more readily reconstructed than those of second-language memory items, leading to superior first-language recall accuracy.

These results support the notion of the possible collaboration between short-term memory and long-term memory on the basis of an episodic buffer (Baddeley, 2012) or the existence of a semantic buffer (Larigauderie, Michaud & Vicente, 2011). This notion is also supported by Messer, Leseman, Boom & Mayo (2010). They indicate that the recall rate in sequences of foreign words is lower than for sequences of words in participants' first language. However, after training, the recall accuracy in second language (as well as first language) increases due to an increase of long-term memory engagement.

In summary, the aforementioned studies indicate that factors other than phonological factors contribute equally to working memory or verbal short-term memory, concentrating on the importance of non phonological factors or psycholinguistic variables. Therefore, the idea that connections exist between the lexical and semantic features of words and their phonological features (Jefferies, Frankish & Noble, 2009) is established. Although explanations for these phenomena vary across scientific disciplines and according to the specific experimental designs used, these findings clearly raise questions over the importance of semantic factors and, more specifically, the collaboration and/or mediation between long-term memory and working memory.

An alternative but similar approach is proposed by studies following a different methodology. These mainly neuropsychological studies indicate that long-term memory contributes to/mediates on working memory or verbal short-term memory although there are also findings supporting a slightly different perspective (Haarmann & Usher, 2001). According to this view non phonological factors and, more specifically, semantic factors participate not only in retrieval of information from long-term memory but also in encoding processes within working memory. In other words, these studies raise the issue of the existence of a semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011). These two types of intepretations correspond to the two ways by which long-term memories and/or strategies participate on working memory.

They were crystalised using data indicating the importance of semantic factors in working memory. In summary, both of them evince the significance of the episodic buffer (Baddeley, 2012) or the semantic buffer (Haarmann & Usher, 2001 ; Larigauderie, Michaud & Vicente, 2011).

2.5 Semantic encoding in working memory

Although research has only recently established solid findings for the participation of semantic traces or semantic encoding in working memory and verbal short-term memory (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015), early evidence for this approach and specifically the properties of the semantic similarity effect were already reported in the sixties and early seventies (Baddeley & Levy, 1971; Baddeley & Ecob,1970; Baddeley, 1966; Baddeley & Dale, 1966; Underwood & Goad, 1951). However, it does have to be clarified that these studies mainly underpin the idea that participants' recall of verbal information relies heavily on the phonological representations of the stimuli (Bower, 1974). However, the approaches do not minimise the effect of semantic factors such as semantic category on the number of correctly recalled items in relevant experimental conditions. In relevant research, one of the classically studied semantic factors is the semantic similarity effect, otherwise known as the semantic relatedness effect. According to this effect, items and words are better recalled when they are all drawn from the same semantic category (e.g. all the items of the list are musical instruments or animals) (Baddeley, 2007). Furthermore, two crucial, well supported effects, demonstrating the contribution of semantic mechanisms to short-term maintenance of verbal material are the word class effect and the concreteness effect.

In relation to the existence of findings supporting the participation of semantic factors in working memory Baddeley (1966) performed three experiments. Using these experiments he finds that the semantic similarity effect is significant. In particular, adjectives with similar meanings are better recalled than adjectives with dissimilar meanings. He also reports that acoustic similarity effect is greater than the semantic similarity effect (Baddeley, 2000b; 2012; Campoy, Castellà, Provencio, Hitch & Baddeley, 2015; Larigauderie, Michaud & Vicente, 2011). However, analysis of the data does raise some concerns for this current research because the participants' performance was scored in terms of percentage correct sequences and non parametric tests were applied (Saint-Aubin & Poirier, 1999).

Baddeley & Dale (1966) performed three interelated experiments in regard to the target phenomena of acoustic and semantic similarity. They reported a significant retroactive inhibition effect on working memory in the first experiment of this study. They then failed to confirm the same findings in the second experiment of the same study, indicating that semantic factors do not have a negative effect on working memory or verbal short-term memory. This data reveals that the effect of semantic factors and, more specifically, the semantic similarity effect is sensitive to the experimental manipulations and the decoding of the data (Saint-Aubin, Ouellette, & Poirier, 2005).

Baddeley & Ecob (1970) then examined three possible explanations for memory with regard to verbal material. They propose that verbal information memory is comprised of two components, one is based on the acoustic properties of the presented words and the second depends on the semantic properties of the information. The first is labile and the second is durable. The main idea of this assumption is the relationship between working and long-term memory. They base their explanation on the distinction between the process of encoding and the rate of forgetting the presented information. They conclude with three possible alternatives. The first explanation is compatible with the initial model of working memory proposed by Atkinson and Shiffrin (1968) indicating that verbal information is encoded acoustically in short-term memory and after that it is processed in long-term memory semantically. The second explanation reflects Baddeley's initial model of working memory (1966). According to this view the material is encoded either phonologically or semantically. Finally, the third explanation is the basis for Baddeley's multicomponent model of working memory (2012), indicating that verbal information is encoded both phonologically and semantically. They conclude that word sequences can simultaneously be encoded both phonologically and semantically. It is clear that this approach highlights the importance of the episodic buffer. This explanation is also compatible with Haarmann and Usher's (2001) model which introduces the concept of a semantic buffer. In this thesis data is interpreted according to the third view establishing the importance of the episodic and/or semantic buffer.

Baddeley & Levy (1971) performed three experiments. The first experiment contained two factors; semantic similarity and semantic compatibility, with two levels each. The two factors were combined in a 2 X 2 design to provide conditions; compatible or incompatible lists comprised of four similar or dissimilar nouns coupled with four semantically similar or dissimilar adjectives (for example, condition of

compatible and semantic similar adjectives: PRIEST–MORAL, MINISTER–RELIGIOUS, VICAR–PIOUS, PARSON–GODLY). The analysis reveals significant main effects of the semantic similarity factor and the compatibility factor. Additionally, the interaction of the factors was also significant, revealing that the semantic similarity effect was significant in the compatible conditions, but not significant in the incompatible conditions. The second experiment was similar to the first in regard to the studied factors. However, the stimuli generated were presented in a different format. The results of the second experiment were similar to the first experiment. Finally, the third experiment was almost identical to the second. The analysis reveals a significant similarity decrement for the compatible delayed condition but not for the others. Although the results of this study were interpreted as supportive of the idea of the absence of semantic encoding in working memory, the data allows further exploration on the basis of new theoretical approaches (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015).

Underwood & Goad (1951) performed a study primarily testing Gibson's theory of verbal learning (Gibson, 1942) and the McGeoch differential forgetting theory (McGeoch, 1942). In particular, the experiment was designed to ascertain if intra-list similarity is a variable in determining whether or not distribution of practice facilitates serial learning of words. The results indicate the confirmation of Gibson's theory of verbal learning, while the analysis contradicts the McGeoch differential forgetting theory. Although there was no direct comparison between high similarity lists and low similarity list of words the results nevertheless indicate that the factor of semantic similarity cannot be neglected. The possible effect of the similarity factor should therefore have been properly and statistically investigated as the results indicate a possible interaction between the conditions if the factor of semantic similarity was included as a separate main factor.

Although the early evidence for participation of semantic traces or semantic encoding in working memory and verbal short-term memory were already reported in the sixties and early seventies, the interpretation of these findings did not establish an efficient explanation of the relevant phenomena (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). This preliminary data and these findings were later overshadowed or differently interpreted by research oriented towards the approach supporting the main role of phonological encoding in working memory/verbal short-term memory. Later evidence, however, establishes the notion that performance in working memory and

verbal short-term memory tasks may rely on both phonological and semantic encoding as well as non phonological factors. This approach, supported by solid evidence, demonstrates a collaboration and/or mediation between long-term memory and working memory.

Additionally, neuropsychological research has previously raised a slightly different perspective with regard to the encoding of semantic information in working memory and the collaboration between working memory and long-term memory. These studies concluded the existence of a semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011). According to this view encoding processes are present within working memory in the form of a semantic buffer (Haarmann & Usher, 2001). This view is not disimilar to the aforementioned perception of Baddeley (2012) although the interaction between working memory and long-term memory operates in different ways.

Recent research indicates that the effect of semantic factors in working memory is significant in conjunction with phonological and non phonological factors (Campoy & Baddeley, 2008; Baddeley, 2007; Martin, 2005; Saint-Aubin, Ouellette & Poirier, 2005; Haarmann & Usher, 2001; Walker & Hulme, 1999; Poirier & Saint-Aubin, 1995). In particular, two crucial effects supporting the contribution of semantic mechanisms to short-term maintenance of verbal material are the word class effect and the concreteness effect, othewise referred to as the imageability effect.

The concreteness or imageability effect describes the more successful immediate recall accuracy of concrete/highly imageable words over abstract/low imageability words (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015; Acheson, MacDonald & Postle, 2011; Romani, McAlpine & Martin, 2008; Walker & Hulme, 1999; Bourassa & Besner, 1994). Walker and Hulme define the effect as: “Concreteness may be defined as a measure of the extent to which a word denotes a material object as opposed to an abstract quality, state, or action” (1999, p. 303). This effect has been studied extensively in relation to long-term memory tasks, while some methodic attempts have also been applied to working memory tasks. Bourassa and Besner (1994), for exemple, report significant concreteness effects among other effects in their experiment. They interpret their findings with regard to imageability and suppression as demonstrating that the semantic properties of long-term memory information are characteristics that support serial order and free recall. Walker and Hulme (1999) also found concreteness effects in a serial recall task. They argue that the concreteness and word length interaction is not

significant, indicating the importance of semantic factors. Additionally, in regard to the serial position of the items they note that the recall of concrete and abstract words differs significantly in all serial positions except for the first and last. However, these studies did not test the relevant effect in relation to other semantic factors. This particular proposition was investigated by Poirier & Saint Aubin (1995). They suggest that the recall of items improves when items are grouped by semantic category, indicating that other semantic factors and processes might have greater influence on immediate recall than the concreteness effect.

Campoy, Castellà, Provencio, Hitch and Baddeley (2015) demonstrate that the concreteness effect in verbal short-term memory experiments/tasks is significant. They see the concreteness effect as a consequence of semantic encoding in working memory, with immediate recall of concrete words benefiting from richer and more distinctive semantic representations. They performed three related experiments in this particular study. The findings indicate that item errors with abstract words are significantly higher than errors with concrete words, suggesting that word concreteness has an effect on immediate memory for item identity rather than order of information. The results indicate that with slower presentations if semantic encoding depends on specific, time reliant strategies, the outcome is a greater concreteness effect. The interpretation of these results attributes differences in regard to the time reaction to "the greater involvement of the episodic buffer with slow presentations, with concrete words benefiting from richer and more distinctive multidimensional representation in this buffer" (Campoy, Castellà, Provencio, Hitch and Baddeley, 2015, p. 310).

Their approach further suggests that because concrete items have more imageability than abstract words, this will become a strategy to benefit the recall of concrete words to a greater extent. However, the results did not in fact confirm the strategy approach and analysis on imageability actually indicated that the concreteness effect in standard working memory tasks depends on automatic encoding of semantic information. Although this interpretation demonstrates to some extent that the concreteness effect does not rely on the intentional collaboration between long-term memory and working memory, it does not exclude the qualitative encoding of the items within short-term memory. This approach is thus in parallel with the notion of a semantic buffer (Larigauderie, Michaud & Vicente, 2011) leaving unattached the proposal for an automatic encoding of semantic information in relation to long-term memory.

Furthermore, the contribution of semantic maintenance in verbal short-term memory experiments is supported by neuropsychological research. Studies of patients with short-term retention of semantic representation deficits indicate that the poor accuracy of these patients with regard to immediate item recall is the result of the impairment of semantic control mechanisms rather than a specific semantic short-term memory deficit (Hoffman, Jefferies & Ralph, 2011). Additionaly, Shivde and Anderson (2011) conclude that the patients specific disorder performance in immediate recall tasks is not necessarily attributable to the active process of semantic representations in short-term memory. They provide evidence of semantic maintenance by using a specific process that they term the concurrent probe paradigm. Martin, Saffran and Dell (1996) further demonstrate that aphasic patients with a lexical-semantic deficits have poor perfomance in recalling items at the beginning of a list in a serial recall task. On the other hand, patients with a more standard impairment of phonological short-term memory deficit reveal an advantage in recalling the initial words of the list. Martin, Saffran and Dell (1996, p. 85) interpret these findings using the hypothesis of retrieval time. They hypothesise that "early items are more susceptible to semantic effects because they have more time to activate the corresponding semantic representations in long-term memory".

Finally, Romani, Galluzzi and Olson (2005), using neuroimaging research, demostrate the role of the left inferior prefrontal cortex in terms of a deficit in retrieving semantics. They argue:

> this work has shown that simple semantic judgments about words (for example, concreteness or animacy judgments) activate this region and that the degree of activation predicts later episodic memory for those words (Romani, Galluzzi & Olson, 2005, p. 225).

In their case study, they report that their patient suffered from a severe episodic memory deficit although his semantic knowledge was intact and his performance was improved when the encoding time was increased. This indicates that working memory is determined not just by phonological factors but also by lexical-semantic factors. It has also been shown that different cognitive impairments may have different impacts on recall at various serial positions. Acheson, MacDonald and Postle (2011, p. 45) argue that:

> if the maintenance of information in verbal working memory is achieved by virtue of activation of language-production architecture, this leads to the prediction that disrupting

> semantic processing should influence the relative activation of lexical-level representations, thus influencing serial ordering.

This indicates the importance of the episodic buffer (Baddeley, 2012) or the presence of a semantic buffer (Larigauderie, Michaud & Vicente, 2011).

Only a few attempts have been made to study the word class effect. One of the main analytical attempts was carried out by Tehan and Humphreys (1988). They report a significant word class effect. In particular, they note that the recall accuracy of content words (adjectives, nouns) is better than the recall accuracy of fuction words (prepositions, conjunctions, etc.). Their experiment included articulatory suppression and the effect was not eliminated even under the manipulation of this articulatory suppression. Their findings indicate the importance of lexico-semantic factors in working memory. Additionally, they attribute significance to the word class effect in terms of contribution to a long-term memory store or procedure as these findings could not be explained in terms of a stimulus frequency effect. In other words their findings clearly indicate the importance of the episodic buffer.

Bourassa and Besner (1994) replicate and present similar results to the work of Tehan and Humphreys (1988). They carried out three related experiments, finding better recall for content words than function words, and thus confirming the word class effect. Their experiment included articulatory suppression. The advantage provided by the content words was found to be stable regardless if the presence or absence of articulatory suppression. However, the word class effect did disappear when the two classes of words, content and function words, were equated for imageability. Bourassa and Besner interprete these findings to indicate that the grammatical class effect is a by-product of an imageability effect, concluding that "imageability made a significant contribution to serial recall performance independently of the effects due to the articulatory loop" (Bourassa & Besner, 1994, p. 123).

In summary, there is general agreement that semantic encoding has a significant role in immediate serial and free recall. However, interpretation of the effect has previously been based on a variety of different accounts. For example, Baddeley (2000; 2012) attributes the importance of semantics in terms of working memory to the influence of long-term memory. According to the multicomponent working memory framework Baddeley proposes that the episodic buffer provides a link between long-term and working memory, accounting for the effects of semantic encoding. Similarly, the reintegration approach (Hulme et al., 1997; 2003) indicates that immediate recall

requires the participation of reconstructive strategies by which degraded phonological items are redintegrated on the basis of long-term representations about the processed words. The extended version of this hypothesis, developed by Saint-Aubin and Poirier (1999) (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015) posits that semantic information improves redintegration accuracy by providing additional clues that minimise the number of appropriate candidates in long-term memory. A further approach proposes a separate semantic buffer within working memory (Martin, 2005). This theory is supported by studies of brain damaged patients (Majerus & Boukebza, 2013; Martin, 2006 Freedman & Martin, 2001), as well as neuroimaging dissociations (Martin, Wu, Jackson, Freedman & Lesch, 2003), and from behavioral data (Haarmann, Cameron & Ruchkin, 2003; Haarmann & Usher, 2001).

2.6 The semantic similarity/semantic relatedness effect

One of the most significant phenomena in semantic encoding is the semantic similarity effect, otherwise known as semantic relatedness effect. Research into working memory and specifically into item recall has shown that items and words are better recalled when they are all drawn from the same semantic category (e.g. all the items of the list are musical instruments or animals) (Baddeley, 2007). Attempts to investigate this specific effect have been part of an ongoing debate over the importance of semantic factors in working memory performance and its processes. Much relevant research has concentrated mainly on verbal short-term memory. The qualitative characteristics of the semmantic similarity effect is therefore considered as crucial in investigating the relationship between working and long-term memory. Two theories have been developed with regard to interpretation of the semantic similarity effect reflecting the analyses followed in order to explain the general semantic encoding in working memory.

The first analysis supposes that the effect of semantic similarity is related to long-term memory organisation. The idea that long-term memory factors and processes influence working memory performance tasks has long been accepted (Saint-Aubin, Ouellette & Poirier, 2005; Poirier & Saint-Aubin, 1995). This explanation is mainly based on the idea that processing of semantic information in working memory is achieved through the function of the episodic buffer. This buffer is a key component of Baddeley's multilevel model which mediates the collaboration between working and long-term memory (Baddeley, 2012). The episodic buffer is assumed to be a limited capacity store in which information from short-term stores and long-term memory can

be integrated into episodic chunks. An alternative analysis was developed by neuropsychological research. This approach explains the effect of semantic similarity on the basis of a semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011). According to this view, encoding processes of semantic information are present within working memory in the form of a semantic buffer. This subtype of working memory is responsible for the encoding and processing of semantically similar words (Haarmann, Cameron & Ruchkin, 2003; Haarmann & Usher, 2001; Martin & Freedman, 2001). These two analyses (redintegration model and semantic buffer), corresponding to the two ways by which long-term knowledge may contribute to short-term storage, have several factors in common. They both consider the implementation of a mechanism for the retrieval of information from long-term memory, which in one case is only involved during retrieval (redintegration model), and in the other is involved right from the encoding (semantic buffer).

Although the effect of semantic similarity traditionally has been associated with long-term memory processes, it has nevertheless been used to carry out significant research in relation to working memory and verbal short-term memory. The effect has been investigated over recent decades, leading to stable but also to some extent contradictory results (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). The similarity effect has been implemented in various ways due to the different types of adapted experiments (Saint-Aubin, Ouellette & Poirier, 2005). The data from studies is therefore sensitive to applied experimental manipulation. In particular, it is affected by the type of required action by the participants, that is, actions requiring the maintenance of items or the maintenance of the order of the provided information (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). In other words, semantic similarity does have different effects in relation to different tasks (Cowles, Garnham & Simner, 2010). Other studies do indicate that the effect of semantic similarity is constant and is not sensitive to type of experiment undertaken, that is, immediate item or serial recall experiment (Saint-Aubin, Ouellette & Poirier, 2005). In terms of experiments, studies of verbal short-term memory in relation to semantic similarity usually involve two main approaches, investigating the effect using immediate free recall or immediate serial recall paradigms. The aforementioned area of research also incorporates experiments using delayed free recall (DFR) in which a short distraction period is interpolated between the final list item and the start of the recall period (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015).

In general, the argument that there is a beneficial effect with regard to semantic similarity on immediate free recall is relatively well accepted (Saint-Aubin & Poirier, 1999). However, research targeting the specific beneficial effect of semantic similarity in immediate serial recall experiments does nevertheless indicate that the beneficial effect is not consistently found (Baddeley, 2012; Saint-Aubin & Poirier, 1999). Numerous studies have investigated the semantic similarity effect, and will be summarised below. A critical concept of this research is based on semantic similarity as an appropriate factor for studying the memory search set called upon at recall. It is traditionally accepted that the semantic category shared by the list of words in a semantically related list can be used as an additional retrieval cue to the stable factors of phonological information (Saint-Aubin, Ouellette & Poirier, 2005). This is also the main idea of redintegration theory. It is therefore considered appropriate for the purpose of this study to present summaries of the significant studies, and evaluate them in regard to their scientific importance (that is, the number of citations).

In summary, any evaluation of the efficacy of each model or group of approaches is not straightforward. We have to take into consideration the predictability of the models as well as the appropriateness of each model in terms of specific predictions with relation to the influence of semantic information stored in long-term memory on the processing of working memory. It is also essential to keep in mind that none of these models provides an unchallenged explanation for the predictability of these phenomena, except perhaps the Saint-Aubin, Ouellette and Poirier model (2005). Additionally, the interpretation of obtained data in these studies can rely on different theoretical approaches. The absence of a unified model providing sufficient explanation may be the reason why there has been little detailed investigation of semantic long-term memory effects on short-term recall to date.

2.6.1 Significant studies investigating the semantic similarity/semantic relatedness effect

The special characteristics of this phenomenon are crucial to the establishment of a solid theory that covers the interaction between semantic long-term memory representations and working memory. Therefore, it is absolutely essential to offer an overview and some analysis of the most influential studies in this area. However, it must also been remembered that the majority of relevant studies have only indirectly examined the phenomenon as the semantic similarity effect is commonly reported in relation to other phenomena.

Perhaps the most significant research in terms of semantic similarity has been carried out by Saint-Aubin and Poirier. In their experiments, they explore semantic similarity effects in terms of both item and order memory. Participants were asked to study lists of items that were either all from one semantic category or were completely unrelated to each other. The authors argue that categorical similarity is advantageous to item memory but has little effect upon order memory; in effect, across conditions, order errors are proportional to the number of items recalled. Since more items are recalled for categorised lists, there is a proportional increase in order errors. In explaining their results, Saint-Aubin and Poirier suggest that the taxonomic category can be used as an extra retrieval cue supporting recall, leading to better item recall and a stable level of order errors per item.

Poirier and Saint-Aubin (1995)

Poirier and Saint-Aubin's (1995) study is considered extremely significant in regard to the use of appropriate methodology, target experimental questions and scientific impact on the research area of working memory. The starting point of the study is the working memory capacity limitations as observed in terms of memory span performance. Baddeley's model (Baddeley, 2012) and specifically the operation of the phonological loop indicates that there is a competence between the decay of a phonological representation and the operation of the rehearsal procedure. Poirier and Saint-Aubin (1995, p. 385), in line with relevant literature, conclude that "a number of studies have called attention to long-term memory effects in memory span tasks and their relationship to the articulatory loop proposal". They comment that the reported results of previous studies indicate the importance of the articulatory loop proposal in assuming that verbal information processing is independent of non-phonological factors. However, they argue that the interface between long-term and working memory can nevertheless be established and mapped out. They also explain the absence of such interpretations in relation to experimental manipulation and proper data analysis. In general terms, they support the idea that "long-term memory can contribute to recall by supporting interpretation of degraded representations from a short-term verbal store" (p. 398).

In particular, Poirier and Saint-Aubin (1995) aimed to examine the influence of the semantic similarity effect on immediate serial recall and its interaction with articulatory suppression manipulations. The study consisted of three interrelated experiments. An open-word pool technique was considered as most appropriate for the

experiment. Specifically, the first experiment compared immediate serial recall performance between stimuli comprised of semantically similar word lists and lists of words from different semantic categories. In the second experiment the same conditions were used as well as incorporating manipulation of articulatory suppression during item presentation (two conditions; with articulatory suppression and without articulatory suppression). The third experiment replicated the second, incorporating the articulatory suppression conditions in the phases of presentation and recall. In general, the advantages of the semantic similarity effect in contrast to the semantic heterogeneous lists was observed in all three experiments. Analysis of the results indicates that long-term memory representations contribute to working memory performance even if the processing of verbal information is based on phonological decoding. This is explained by the introduction of the theory of redintegration indicating that better item information recall for semantically similar words is observed due to long-term memory contribution at the recall stage. Additionally, this advantage is not based on the properties of the phonological loop, which is only responsible for the decoding and not the rehearsal procedure. The participants' performance was scored according to a free-recall criterion. Furthermore, the recorded errors were categorised allowing the investigation of the semantic similarity effect on order errors.

Analysis of the results revealed for the first experiment a significant advantage in terms of the semantic homogeneous condition over the heterogeneous condition. The investigation of the order errors, unlikely in previous studies, indicated that there was a higher number of order errors in the heterogeneous condition than in the homogeneous condition. For the second experiment the same procedure was followed, introducing the research hypothesis: "If the category advantage is related in any significant way to articulatory loop operation, then the effect should be reduced or abolished by articulatory suppression" (Poirier and Saint-Aubin, 1995, p. 390). The results showed a significant main effect of the semantic similarity factor in favor of the semantic homogeneous lists. A significant effect of the suppression factor was also observed. The interaction between semantic grouping and suppression conditions was close to significance. In regard to the second dependent variable, order errors, there was a significant effect of the suppression factor but not for the semantic similarity factor, indicating no significant semantic similarity disadvantage. The interaction was also significant indicating that there was a tendency for higher order errors in the suppressed homogeneous condition. The third experiment allowed a clear image of the possible effect on item and order recall accuracy. The data from the third experiment revealed a

significant main effect of the semantic similarity factor in favour of the semantic homogeneous lists. A significant effect of the suppression factor was also observed. The interaction between semantic grouping and suppression conditions was also significant. The same tendency was visible for the second dependent variable revealing no disadvantage of the semantic similarity effect on order recall.

In summary, the advantages of the semantic similar condition and the stable detrimental effect of articulatory suppression were present. Any advantage gained from semantically homogeneous lists was not negatively affected by articulatory suppression for presentation and recall conditions. Therefore, the semantic similarity effect is independent of articulatory loop operation. The study clearly supports the original idea of the redintegration theory indicating that "long-term memory can contribute to recall by supporting interpretation of degraded representations from a short-term verbal store" (Poirier and Saint-Aubin, 1995, p. 399).

Saint-Aubin and Poirier (1999b)

Saint-Aubin and Poirier (1999b), in acordance to previous research, establish their explanation of the semantic similarity effect on item recall using the retrieval-based hypothesis. Allthough the positive effect of semantic similarity on free recall is constant in the majority of studies, the effect is not constantly found in terms of order recall. Saint-Aubin and Poirier (1999b) attribute these contradictory results to order retention measurements applied in previous research. In verbal working memory tasks, order retention is assessed by using tasks requiring the reconstruction of order, or by using an immediate serial recall task, and then computing the number of order errors. However, these techniques retain a probability of inappropriate measurement, especially in the case of semantic similarity effect. This assumption is logically supported as the semantic relatedness manipulation results in more items to be recalled. Therefore, the probability of an order error is increased. On the basis of this hypothesis, Saint-Aubin and Poirier (1999b) replicated the design of their previous study, this time introducing a different approach to measuring order recall by computing the proportion of order errors per item recalled. This time they performed four experiments but they changed the auditory stimuli into visual stimuli and used longer lists. The fourth experiment included an order reconstruction task.

In summary, the analysis of the data collected in the four experiments can be outlined in two sentences. In all four experiments, there was a significant positive main effect of the semantic similarity factor for item recall. Secondly, there was no

significant semantic similarity decrement in immediate order recall tasks. In particular, the positive semantic similarity effect on item recall was strong, especially in terms of the second experiment. The factor accounted for 27% of the total variance. In relation to the manipulation of suppression, it was observed that the effect of semantic similarity not only remained unaffected by the manipulation of articulatory suppression but was stronger. In regard to immediate serial recall, a disadvantage was observed. However, when appropriate statistical controls were applied this disadvantage vanished as expected. Additionally, in experiments three (a serial reconstruction task was included) and four (limited word pool) there was no observation of semantic similarity decrement. The manipulation of articulatory suppression was introduced in order to check if subvocal rehearsal mediates the influence of semantic similarity on serial recall. However, as Saint-Aubin and Poirier (1999b) predicted there was no such an interaction, indicating that long-term memory representations are responsible for retrieval of degraded items either through decay or interference. Overall, the semantic similarity effect on free and serial immediate recall tasks can be clearly explained by the retrieval-based hypothesis. The effects of long-term memory representations can thus be implied for this factor in the same way as for factors such as lexicality and frequency.

Saint-Aubin and Poirier (1999a)

In this study Saint-Aubin and Poirier (1999a) discuss the effect of semantic similarity in the light of redintegration theory, suggesting that degraded phonological information should be processed by a reconstruction strategy based on long-term knowledge of the to-be-remembered words. The paper indicates that semantic similarity influences item recall but does not have possitive or negative effect on the order of information. The latter is only affected by the lexicality effect. The main argument of this study is that the order retention measures applied could be responsible for inconsistencies in the relevant studies. In other words Saint-Aubin and Poirier attribute the observed negative effect of semantic similarity on immediate serial recall to inappropriate measurements and especialy order retention measures. At the same time they provide data revealing a possitive effect of the factor.

Saint-Aubin, Ouellette and Poirier (2005)

Saint-Aubin, Ouellette and Poirier' (2005) study specifically seeks to answer the question of the origin of inconsistencies in serial order recall in terms of the semantic similarity effect. They clarify the two conceptions of semantic similarity and they conclude that they are not distinguished. Thus, a list of words can share the same

semantic category (for example, all vegetables, vehicles) or the list of items can be linked in an abstract notion (for example, all the items are related to the class; teacher, student, desk whiteboard). Only a few models have attempted to include both conceptions although restricted to the most recently presented item (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). In general, during item recall from long-term memory, the category shared by list items is used as an informative cue. In regard to long-term memory research, an extended search or a restricted search could affect the recall accuracy and time. The list of to-be-recalled items could also be used as an additional retrieval cue, restricting the number of recall candidates. Saint-Aubin, Ouellette and Poirier (2005) test whether words are more effectively recalled when they are all derived from the same semantic category.

Their experiment included both articulatory suppression manipulation or non articulatory suppression manipulation, and the tasks were divided into two categories; semantically similar items (same category including both conceptions of similarity) and non semantically similar items. The results confirmed the experimental hypothesis as far as the expected positive effect of semantic similarity not only on item recall but also on serial recall tasks. In particular, the semantic similarity effect was significant both under strict serial scoring analysis and also after serial scoring correction. Although the descriptive results revealed that the item recall performance was higher in quiet conditions (non articulatory suppression) than in articulatory suppression, the effect was significant under both conditions of articulatory suppression and the quiet condition. Thus, there was no significant interaction between the semantic similarity factor and the trial (that is, the within subjects factor) indicating that the effect of semantic relatedness had similar size in all trials. Finally, there was no difference between lists sharing the same semantic category (for example, all vegetables, vehicles) and the lists of items linked by an abstract notion.

These results were interpreted by Saint-Aubin, Ouellette and Poirier (2005) as a supporting argument for the reconstruction hypothesis. In particular, according to the reconstruction hypothesis, similar category lists have an advantage due to the increased probability of retrieving the most appropriate long-term memory information. This can be accomplished either because the category is used as a retrieval cue or because the information under the same category is already more activated due to the associative links (Hulme, Stuart, Brown & Morin, 2003; Stuart & Hulme, 2000).

Poirier, Saint-Aubin, Mair, Tehan and Tolan (2015)

Poirier, Saint-Aubin, Mair, Tehan and Tolan's (2015) study aimed to test the hypothesis that working memory relies on activated long-term memory representations and networks. The semantic similarity effect and specifically the semantic category shared between the to-be-recalled items were manipulated in this study in order to test the aforementioned hypothesis. According to Acheson, MacDonald and Postle (2011) semantically similar lists of words generate more order errors than unrelated lists, because the latter minimises the level of inter-item activation. This prediction is supported by a number of studies (for example, Tse, Li & Altarriba, 2011). However, recent research indicates the opposite, suggesting that "order errors are proportional to item recall, and semantically related lists produce better item recall" (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015, p. 491).

According to the hypothesis of Poirier et al. (2015) manipulating the semantic activation level of items within a list can influence serial ordering in predictable ways. In particular, words from the same category rely on their long-term associative links, that is, words from the same category tend to occur more frequently and therefore have stronger associative links. Thus, in a list of items noise makes it difficult for an item and the related items to be selected because of the increased number of candidates and increased mutual inhibition. This is called competitive queuing. This noisy competition between the activated response candidates typically suppress the activation of any selected response, preventing perseverance.

In other words, the philosophy of the experiments conducted by Poirier, Saint-Aubin, Mair, Tehan and Tolan (2015) can be summarised as follows. A list of words for immediate serial recall activates the lexico-semantic network. If the words are from the same semantic category the competing queue indicates, at the stage of recall, that the first item will be selected and recalled. This item will be removed facilitating, in this way, the selection of the second item and so on. In the experiment the first three items and the fifth were from the same semantic category but the fourth was not. According to the hypothesis the fifth item should be activated because of its semantic similarity to the first three. This activation would result in the fifth item then migrating towards an earlier position more often than a non target item studied in the same position. The results of the study confirmed this prediction revealing that "categorized lists lead to heightened network activation, which produces better item retrieval as well as perturbation of the representation of item order" (Poirier, Saint-Aubin, Mair, Tehan &

Tolan, 2015, p. 498). Overall the findings were interpreted as an indication that short-term memory relies on activated long-term memory representations and networks.

Neale and Tehan (2007)

Neale and Tehan (2007) provide findings in support of the redintegration model. They assume and then prove that the phonological trace loses its fidelity in recalling as age increases. Therefore, short-term memory tasks become more difficult as a person ages. However, recall can still operate through redintegration, where long-term information, phonological or lexical, is implemented to reconstruct the memory trace. According to their interpretation of the collected data they conclude that even though there are differences in the absolute level of recall across age groups, the redintegration process is identical for both younger and older people. As a result of their experiment they report a significant similarity effect in free recall but not in serial recall. In particular, they note a tendency for the size of the similarity effect to increase as task difficulty in- creases. Furthermore, comparisons of the slopes indicates that the underlying processes are much the same for both younger and older adults. In summary, their findings indicate that as task difficulty increases, the memory trace, presumably phonological in nature, weakens its creditability. Therefore, accessibility of potential candidates for recovery of the memory trace is increased while semantic similarity narrows the search set in long-term memory, resulting better recall. Thus, they conclude that performance can be accurately predicted from semantic similarity and from knowledge of task difficulty with item scoring, but not with order scoring.

Larigauderie, Michaud and Vicente (2011)

Larigauderie, Michaud and Vicente's (2011) significant study sought to investigate the involvement of long-term memory semantic factors in immediate recall tasks and the individual differences in strategic retrieval ability (that is, the ability to activate representations in long-term memory in a controlled way). Although the aim of the study was to investigate the strategic retrieval abilities in working memory, the experiment implemented elements of the semantic similarity effects. In particular, the experiment included lists containing 12 words belonging to three or four semantic categories of three or four words each. Analysis of the results revealed a higher number of represented semantic categories in a greater number of words grouped by semantic category than ordered recall. Furthermore, the participants recalled more items grouped into each semantic category than they did when provided with mixed lists. There were also significantly more items per category in the item recall than in the serial recall

condition. This indicates that the participants spontaneously tended to organise the presented material according to semantic principles. However, these encoding strategies were affected by individual differences in regard to the strategic retrieval ability. Generally, the authors conclude that strategic retrieval ability orients participants towards making greater use of the semantic properties of the materials during the immediate free or serial recall task.

Tse (2010)

Tse (2010) carried out a study aiming to examine whether judgments concerning the relative order of two words on a study list of eight items would be positively or negatively affected when the two words either belonged to the same semantic category or a different category. The study contained two interelated experiments. Overall Tse concludes that semantic similarity resulted in slower and less accurate recency judgments. He also argues that semantic similarity was seen to have a negative effect on order memory per se but does not report if the same negative effect was present in item recall. However, analysis of the differences between the two experiments revealed that a semantic similarity effect switch from weakly positive to null. In particular, Tse notes: "These differences include: (a) the item and order memory tests were now manipulated within participants, rather than between participants as in Experiment 1, and (b) a 2AFC recognition test, rather than a pair recognition test, was used" (p. 650). Furthermore, other factors such as the inter-item free associations were not taken into consideration.

Tse (2009)

In 2009, Tse performed a similar experiment to the Saint-Aubin, Ouellette and Poirier (2005). This was in regard to the distinction between the semantic similarity of a list of items from same semantic category (for example, piano, guitar, saxophone) or different category and a list of items that are semantically associated (for example, pencil, teacher, whiteboard) or not associated. The aim of the study was to investigate "how the associative strength among study items and between study items and their shared theme could modulate the effects of categorical and associative relatedness on immediate serial recall" (Tse, 2009, p. 878). The findings reveal a significant main effect of semantic relatedness; related lists were better recalled than unrelated lists. This effect occurred for both category and associative lists. In regard to the distinction between lists of items from the same semantic category and lists of items semantically associated a significance difference was observed; associative lists were better recalled than category lists. The same pattern of results was also clear for the within subjects and between

subjects comparisons. In contrast to the findings observed in Saint-Aubin, Ouellette and Poirier (2005) Tse suggests a negative semantic relatedness effect in order retention. He bases his explanation of the findings mainly on the properties of the redintegration hypothesis (Hulme, Stuart, Brown & Morin, 2003; Saint-Aubin & Poirier, 1999b). The advantage of the associative lists is explained on the grounds of the effectiveness of the theme-item associative strength. Furthermore, the observed effect is not admitted to the inter-item associative strength because, according to the author the "theory assumes that the redintegration of a study item does not depend on the properties of other items on that list" (Tse, 2009, p. 889).

Tse, Li and Altarriba (2011)

Tse, Li and Altarriba (2011) observe both similar and contradictory results to the findings provided by Saint-Aubin, Ouellette and Poirier (2005); Saint-Aubin and Poirier (1999b) and Poirier and Saint-Aubin (1995). They examined the effects of semantic relatedness on immediate serial recall and serial recognition. They replicated the experiments designed by Saint-Aubin and Poirier while also introducing additional experimental manipulation. They divided the factor of semantic similarity into two sections; "items are from the same category (for example, apple, banana, grape) or whether study items are associated with each other (for example, honey, sugar, sour)" (Tse, Li & Altarriba, 2011, p. 2426). The participants' responses were evaluated with regard to immediate serial recall and serial recognition tasks. The analysis revealed specific major findings. Firstly, the performance was higher for related words (68%) than for unrelated words (58%). Secondly, the semantic similarity effect was stronger for associative lists than for category lists. Furthermore, order errors were more obvious for related items (18%) than for unrelated items (15%). In regard to the serial recognition tasks there was a significant main effect of semantic similarity factor indicating that performance accuracy on related words was lower than unrelated words. Related words were also connected to higher reaction times.

Tse, Li and Altarriba (2011) also introduced a speed stress manipulation. However, they do not provide suffiecient results or methodological information with regard to this manipulation. Their findings can be interpreted as an indication of a negative effect of semantic similarity on immediate serial recall due to the degraded semantic information. The impact on performance is caused by the process of matching the degraded semantic information with long-term representations. The participants did

not often match the correct word during item redintegration. Additionally, it took more time to compare the order of degraded semantic traces of semantic similar items.

Tse, Li and Altarriba (2011, p. 2428) use as a starting point for their interpretation the hypothesis that "semantic traces are degraded as easily as phonological traces". However, they do not provide sufficient experimental findings to support this assumption. Furthermore, they do not offer any interpretation on either how this hypothesis explains the strong positive sematic similarity effect on item recall nor the underlying process of semantic information degradation. Instead they conclude with a general statement: "even though study item representation may facilitate the item redintegration of their traces, participants could still be confused by the order of the degraded traces." (Tse, Li & Altarriba, 2011, p. 2427)

Stuart and Hulme (2000)

Stuart and Hulme' (2000) study sought to test and extend Deese's (1960; Deese & Kaufman, 1957) assumption of word co-occurrence. According to this theory the frequency of word co-occurrence is far more important than the frequency of occurrence of the words per se. Furthermore, he suggests that this effect is behind the frequency effect itself. This assumption is based on the observation that high frequency items have higher inter-item association rates than low-frequency words. Also, lists of words with low inter-item associations reveal data with no significant difference between high and low frequency word lists. Deese (1960) concludes that "This implies that there is little or no intrinsic effect of frequency of usage upon recall and that the covariation of recall scores with frequency of usage occurs because of the higher probability of association occurring between high-frequency words" (p. 342).

Further, Stuart and Hulme (2000) explore the inter-item associations in short-term immediate serial recall tasks, as opposed to the long-term free recall tasks studied by Deese (1960). They predict that "by creating inter-item associations between items in long-term memory, we would improve short-term memory performance for those item" (p. 797). The results of their study support this prediction. The findings indicate that long-term memory processes influence working memory performance. Also, associative links between items in long-term memory have an important effect on working memory performance, suggesting that the effects of word frequency in working memory tasks are related to differences in inter-item associations in long-term memory. Finally, the importance of training is highly significant in eliminating the commonly reported recall advantage for high- over low frequency words. These assumptions are essential with

regard to this thesis as they suggest that the employed strategies of each individual could affect their performance in terms of working memory. Furthermore, these tendencies can be used to explain other reported effects, laying the foundation for other more stable interpretations of working memory procedures and phenomena. Finally, while this researches might not directly address the semantic similarity effect (in regard to stable associations) it does nevertheless raise the importance of associations and similarities (objective or subjective) in working memory.

Tehan (2010)

Tehan (2010) carried out a study in order to test the importance of associative semantic networks in short-term memory. His hypothesis is based on the assumption that the lexical network in long-term memory significantly influences working memory performance and that permanent semantic networks facilitate memory in long-term memory tasks. He hypothesises that this facilitative effect of permanent semantic networks will be present in working memory tasks. The experiment contained lists of intact associatively related items as well as examples where those items had been randomly mixed to produce unrelated lists. The results of the experiment indicate that the associatively related lists are better recalled in order than the unrelated lists. These findings reveal that item interactions amongst permanent associative networks also have an impact upon immediate serial recall. However, the study failed to manipulate any strategies implemented during the process. The results of the experiment did nevertheless confirm the importance of associative semantic networks in short-term memory.

Tse and Altarriba (2007)

Tse and Altarriba (2007), on the basis of Stuart and Hulme's (2000) associative-link hypothesis, performed two experiments. They manipulated inter-item association by varying the intra list latent semantic analysis. The main goal of the study was to test the associative-link hypothesis by "teasing apart the effects of inter-item association and word frequency in immediate serial recall" and by "examining whether this hypothesis can be generalized to explain the word imageability effect in immediate serial recall" (Tse & Altarriba, 2007, p. 674). The analysis reveals that there is a significant positive effect in terms of inter-item association irrespective of serial or item recall. Furthermore, Tse and Altarriba propose that both item- and associative-based mechanisms are essential to account for the word frequency effect in immediate serial recall.

Besner and Davelaar (1982)

Besner and Davelaar (1982) examine the lexicality effect, the word length effect, the similarity effect and the suppression effect on immediate serial recall. Their findings indicate the presence of the semantic similarity effect regardless of the length of the presented words. However, the semantic similarity effect is abolished when the manipulation of suppression is introduced. These results are interpreted as a proof of the importance of the phonological loop process and the influence of long-term memory representations on verbal short-term memory. However, it has to be noted that there was no analysis on free recall performance.

Neale & Tehan (2007)

In support of the redintegration theory, Neale & Tehan (2007) assume that immediate recall can be achieved through the redintegration process even when short-term memory tasks become more difficult. They carried out two related experiments, manipulating the semantic similarity effect and the degree of task difficulty. The results for the first experiment reveal that semantically similar lists are better recalled in immediate serial recall tasks. In particular, the effect of semantic similarity is minimal in recall position performance, but as the difficulty of the task increases the effect of the semantic similarity becomes stronger. The second experiment replicated the first experiment but the phonological similarity effect was manipulated with lists from rhyme categories or from non rhyming sources. While the results replicated the findings of the previous experiment indicating that the semantic similarity effect has an adverse advantage at low levels of task difficulty, this was reversed to a similarity advantage at high levels of task difficulty. However, there was a consistent similarity advantage for item scoring in both experiments. In summary, Neale & Tehan (2007, p. 1949) conclude that:

> as task difficulty increases, the memory trace, presumably phonological in nature, loses its fidelity. Then, as Saint-Aubin and Poirier (1999) suggested, similarity functions enhance the accessibility of potential candidates for recovery of the memory trace. In their terms, similarity narrows the search set in long-term memory.

Goh and Goh (2006)

Goh and Goh's (2006) study examines the semantic similarity effect and proactive interference in relation to the word length effect. The adapted experiments were based on manipulations introduced by Saint-Aubin and Poirier (1999) and Saint-Aubin, Ouellette and Poirier (2005). The semantic similarity effect was manipulated in three different conditions: a homogeneous block in which all items were from the same

semantic category; a homogeneous list, in which the within each list items were from the same semantic category; and a heterogeneous list in which items were from different semantic categories.

The main experimental hypothesis was based on Saint-Aubin, Ouellette and Poirier's (2005) approach to the redintegration model. Therefore, the semantic similarity effect, due to the semantic organisation in long-term memory, provides an extra recall cue and as a result minimises proactive interference effects. The results of this study are considered especially significant due to the large number of participants (# 378). In particular, Goh and Goh observe a significant main effect due to the semantic similarity effect. Their findings also suggest a greater semantic similarity advantage for longer words than for shorter word in terms of the condition of homogeneous lists, indicating that when the difficulty of the task is increased the subjects rely on long-term memory representations. This observation is in accordance with the later study of Neale and Tehan (2007). The authors:

> interpreted their results on the base of redintegration model pointing out that two-process mechanism for recall, a direct read-out from short-term memory is more prevalent for short words, thus obscuring similarity effects, whereas for long words, recall is more likely to in- volve reconstruction from degraded traces (Goh and Goh, 2006, p. 983).

In summary, their results indicate that the semantic similarity effect triggers an alternative retrieval strategy when the retrieval of verbal short-term memory information is not efficient to be processed on the basis of phonological information only.

Roediger and Schmidt (1980)

Roediger and Schmidt (1980) introduce the experimental manipulation of lists belonging to specific categories. Each list of words consists of either semantically dissimilar or semantically similar categories. The subjects were provided with the name of each category. This was considered as a retrieval cue. The experiment required the participants to recall the words of each category in their serial position. Analysis of the results reveals that the similarity of the categories had no significant effect on serial item recall performance. However, as Bauml and Hartinger (2002, p. 219) point out "the similarity effect was studied in relation to lists' similarity and not in relation to the items' similarity. This raises questions over the validity of the experimentation" as the similarity effect of the items was not tested either according to serial recall or free recall.

Smith and Hunt (2000)

Smith and Hunt (2000) report their findings in a study targeting the role of item similarity in retrieval induced forgetting. The stimuli of the experiment were words from different semantic categories. The participants had to indicate either similarities or differences among all the items of a category. After that they had to recall the presented words. Analysis of the data reveals no effect of relational processing on the amount of retrieval induced forgetting but in the case of distinctive processing the authors found a reduction, and even elimination, of the forgetting. These results suggest that distinctive processing of the words reduces the competition between the words, and as a result, reduces retrieval induced forgetting.

Anderson, Green, and McCulloch (2000)

Anderson, Green, and McCulloch (2000) replicate studies cited above, making experimental variations. In particular, the participants in their experiments had to find similarities or unique characteristics among pairs of items from the same semantic category. They argue that in the condition of unique characteristics among pairs there was a retrieval induced forgetting effect. However, this effect was not observed in the similarity condition although they did report a recall improvement effect. The authors interpret the results as an indication that:

> the similarity effect has different and even opposing ways according to the items characteristics and according to the effect of practiced and non practiced items and the similarity between the practiced and non practiced items (Anderson, Green, and McCulloch, 2000, p. 1150).

Bauml and Hartinger (2002)

Bauml and Hartinger (2002) support the beneficial effect of semantic similarity. They introduce an experimental manipulation of different levels of semantic categories (categories and subcategories). In particular, they use two types of lists, one list containing items from the same category but different subcategory and the other list consisting of items highly similar, from the same category and subcategory. The analysis reveals a significant retrieval induced forgetting effect in the condition consisting of items that were drawn from the same category but different subcategory. The same effect is not observed in the condition of highly similar words. The interpretation of the results supports the redintegration model of Saint-Aubin, Ouellette and Poirier (2005), indicating that the existence of differences between the to-be-recalled items has a negative effect in preventing forgetting.

2.6.1.1 Summary

Although the nature of the set of items required to-be-remembered in immediate item and serial recall experiments is not been fully defined, relevant research indicates some solid findings allowing some reliable outcomes (Saint-Aubin, Ouellette & Poirier, 2005). In general, there are some outcomes which are stable and well supported by research argumentation. The effect of semantic relatedness is considered as a significant factor related to long-term memory organisation indicating an interface between working memory and long-term memory (Poirier & Saint-Aubin, 1995). While some recent scholars indicate that there is a beneficial effect of semantic similarity on immediate item recall (Saint-Aubin & Poirier, 1999), on the other hand, the beneficial effect of semantic similarity in immediate serial recall experiments suggests that the beneficial effect is not consistently found. These contradictory findings can be attributed to their individual applied methodologies (Saint-Aubin & Poirier, 1999; Baddeley, 2012) to some extent. Nevertheless, it is traditionally accepted that the semantic category shared by the list of words in a semantically related list can be used as a retrieval cue in addition to other factors such as phonological information (Saint-Aubin, Ouellette & Poirier 2005).

2.6.2 Explanation of the semantic similarity/semantic relatedness effect

Research on the similarity effect fundamentally originates from the experimental data investigating the relationship between working memory and long-term memory. In general terms, the effect was used as a manipulation in order to illustrate role of permanent representations in the functioning of working memory. Therefore, any attempted interpretations of the similarity effect should be based on this relationship.

Several accounts have been developed to explain the role of semantics in working memory and, more specifically, the semantic similarity effect. Indicative models addressing the semantic effects on working memory are the computational models proposed by Gupta (2003; 2009), as well as the psycholinguistic approach proposed by Martin and Gupta (2004) and Martin (2006); the conceptual models proposed by Cowan (1999; Cowan & Chen, 2009); the language processing model proposed by Majerus and Boukebza (2013) and Majerus, van der Linden, Mulder, Meulemans and Peters (2004) in relation to vocabulary; and finally, models proposed by Acheson, MacDonald and Postle (2011), and Buchsbaum and D'Esposito (2008) from the area of cognitive neuropsychology. All these accounts attempt to explain in general terms the processing of semantic effects on working memory. However, the vast majority of the studies that

have been carried out in regard to the semantic similarity effect have so far interpreted the effect on the basis of three main hypotheses and alternative models. These hypotheses and models are similar to each other in regard to the main cognitive structure of working memory as well as in relation to the semantic similarity effect. The majority of them accept and implement to some extent the main structure of Baddeley's multicomponent model (Baddeley, 2000; 2012). However, apart from the observed similarities, they have specific differences in terms of the functions of the proposed structures.

The first hypothesis is based on Baddeley's multicomponent model (Baddeley, 2012) and it was formulated by Saint-Aubin and Poirier (1999; Saint-Aubin, Ouellette & Poirier, 2005). Over the past 30 years this approach has been the dominant hypothesis in explaining the long-term memory effects on working memory recall processes. According to this perspective, it is assumed that participants first encode verbal materials into phonological forms. These phonological forms over time become degraded, either through decay or interference. The subjects initially attempt to retrieve the degraded phonological forms in short-term memory and then match them with the stored phonological and semantic information in long-term memory. This reconstruction process is often referred to as the redintegration process. To explain the categorical relatedness effect, Saint-Aubin and Poirier (1999; Saint-Aubin, Ouellette & Poirier, 2005) propose that item redintegration for related items is facilitated by the participants' long-term knowledge. The category node is implemented as a cue to delimit the number of potential recall candidates within semantic categories and, as a consequence, the redintegration process is more effective than unrelated items. The word meanings are retained and accessed by working memory and, more specifically, by the episodic buffer. These processes are independent from phonological and visual codes (Hamilton & Martin, 2005; Shivde & Thompson-Schill, 2004; Baddeley, 2003; Haarmann & Usher, 2001; Baddeley, 2000; Potter, 1993).

The second hypothesis is based on psycholinguistic and long-term memory network models (Saint-Aubin, Ouellette & Poirier, 2005; Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). While the redintegration hypothesis is considered to be the dominant approach to short-term memory research according to the first hypothesis, the psycholinguistic approach is becoming increasingly accepted. The main tendency of this models is based on the notion that long-term memory representations and especially those involved in language processing are very strongly related to working memory

processing and representation (Acheson, MacDonald & Postle, 2011; Buchsbaum and D'Esposito, 2008). The main difference in relation to the redintegration hypothesis, discussed above, is that the relationship between long-term and working memory in regard to verbal information is not limited to the retrieval stage of short-term recall. However, Saint-Aubin, Ouellette and Poirier (2005, p. 490) conclude for the psycholinguistic approach that:

> there is considerable overlap between short-term memory tasks and language processing; hence, the semantic, lexical, and sublexical networks that are widely thought to underlie language representations are viewed as supporting short-term memory.

In other words this hypothesis suggests that verbal short-term memory does not rely on a separate long-term memory system. Verbal short-term memory is only a temporarily activated system of long-term memory phonological and semantic representations. Additionally, these representations exist and operate within a specific language system (Martin, 2006; MacDonald & Christiansen, 2002). The interactivity between semantic and phonological nodes is seen as potential able to help overcome phonological decay. The semantic nodes support and contribute to phonological coherence in working memory. Although this approach has gained much attention, it leaves unexplained significant phenomena and procedures. For example, even though the model claims that it anticipates parallel effects of lexical/semantic variables in recall and recognition (Jefferies, Frankish & Noble, 2009), it does not explain how the characteristics of the proposed model influence performance in processing specific verbal and semantic information (Baddeley, 2012).

The third hypothesis is based on computational/network models and neuropsychological studies. These experiments raise a slightly different perspective in regard to the encoding of semantic information in working memory and the extent of collaboration between working memory and long-term memory. These studies explain the effect of semantic similarity on the basis of a semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011). According to this view, encoding processes of semantic information are present within working memory in the form of a semantic buffer. This subtype of working memory is also responsible for the encoding and processing of semantically similar words (Haarmann & Usher, 2001; Haarmann, Cameron & Ruchkin, 2003). Computational or network models propose that verbal information is processed in working memory on the basis of networks where lexical and phonological representations are interconnected. In particular, an interactive network

model is necessary in order to explain the effect of semantic information (Roodenrys, Hulme, Lethbridge, Hinton & Nimmo, 2002; Roodenrys, Hulme, Alban, Ellis & Brown, 1994). According to this approach, letter, phonemic and lexical representations are mutually activated and compete with each other. Computational models have also been proposed by Gupta (2003; 2009), Cowan (1999; Cowan & Chen, 2009) and Majerus (2009). In relation to the psycholinguistic models proposed by Martin and Gupta (2004) and Martin (2006) there is an overlap with the computational/network models and the psycholinguistic models.

Another explanation for the semantic similarity effect has been provided by Stuard and Hulme (2000). Their associative-link hypothesis is based on the redintegration theory (Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart 1997). Thus it can be said to be similar to Saint-Aubin, Ouellette & Poirier, (2005) and Poirier, Saint-Aubin, Mair, Tehan & Tolan (2015) redintegration model and they overlap in some extend. Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart's (1997) item redintegration theory assumes that the recall of to-be-remembered word is not affected by other words present in the same context. However, if serial recall is affected by inter-item associative strength, this indicates that serial recall may also be determined by factors that do not affect item redintegration. The inter-item associative strength can be quantified by the mean associative strength among study items in a study list (Nelson, McEvoy & Schreiber, 2004). According to this notion, when two words (for example, teacher and student) are strongly associated, the encoding and later the recall of one item can activate and facilitate the encoding and the recall of the other. Additionally, apart from the effect on item and serial recall of the aforementioned items, due to their associative strength, what has to be taken into consideration is the type of semantic relatedness (for example, associative and category relatedness).

These observations have resulted in the incorporation of an associative mechanism in Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart's item redintegration theory (1997). One such mechanism has been proposed in Stuart and Hulme's associative-link hypothesis: serial recall can be facilitated when the pre-existing, non-directional associative strength between study items in semantic memory becomes stronger. In particular, the encoding and the recall of a word (for example, teacher) activates related words (for example, student). This activation of words facilitates their accessibility and in turn enhances the encoding and recall of these items. Because the spreading activation relies on the inter-item associative strength between

the target words, a strong inter-item association among study words could result in a higher item and serial recall performance.

In general, the explanation of semantically grouped words is mainly interpreted in terms of associations between working memory and long-term memory. This approach provides evidence that working memory is influenced by semantic factors including the semantic similarity factor (Campoy & Baddeley, 2008; Martin, 2005; Haarmann & Usher, 2001; Walker & Hulme, 1999; Poirier & Saint-Aubin, 1995). According to the most supported and defined approaches, the effect of semantically grouped words is accounted for by a two-stage retrieval based framework, in which, at immediate recall, long-term information is used to process or reconstruct degraded phonological traces temporarily processed on working memory (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Although the importance of the phonological loop on verbal short-term memory is established for analysis of relevant phenomena, it does not provide a complete explanation of data from the entire range types of verbal tasks requiring short-term storage and analysis (Cameron, Haarmann, Grafman & Ruchkin, 2005). The most widely held proposal for working memory properties and procedures is the multi store view of Baddeley (Baddeley, 2007; 2012). However, this multi store view of human memory properties and procedures nevertheless retains important and unresolved questions regarding the different subsystems' possible interaction (Baddeley, Hitch & Allen, 2009). An explanation of this potential interaction could highlight how these subsystems enable the coherent operation of the system as a whole. The major problem that the research has left partially unexplained is how information temporary held in working memory interacts with, or is mediated by, more permanent long-term information or mental strategies (Baddeley, 2012).

In summary, the influence of semantic organisation on immediate serial and item recall is strongly linked to the theoretical approach of the interface between working memory and long-term memory (Poirier & Saint-Aubin, 1995). Apart from the tendency to interpret the semantic similarity effect on the basis of the aforementioned models, the phenomenon has to be linked to other factors as well. It is absolutely necessary to link the semantic similarity effect to the semantic encoding processes in working memory in order to explain the effect. The participation of controlled mechanisms in verbal short-term memory is made apparent by the elaboration of strategic semantic encoding which improves performance on working memory tasks.

Furthermore, the semantic similarity effect and the link between long-term memory and working memory has to be examined in relation to specific phenomena as well.

The effect of semantic similarity is mainly bound with four main phenomena and hypotheses. The "chunking hypothesis", the "semantic clustering effect", the "response bursting effect" and the studies related to "associative memory". Chunking is an effective form of strategic encoding that involves the recoding of a set of data into a compressed, efficient form and can extend working memory capacity (Baddeley, Hitch & Allen, 2009; Walker & Hulme, 1999; Bourassa & Besner, 1994; Romney, Brewer & Batchelder, 1993; Cofer, Bruce & Reicher, 1966; Bousfield, 1953; Jenkins & Russell, 1952; Bousfield & Sedgewick, 1944). According to the "semantic clustering effect", the recall of a presented word is more likelly to be followed by the recall of a related or similar word (Manning & Kahana, 2012). The "response bursting effect" is a known phenomenon that refers to the interresponse times of words in the same semantic category. The effect refers to the reported tendency of recalling words/items from the same semantic category faster than those words from a different category (Patterson, Meltzer & Mandler, 1971; Pollio, Richards & Lucas, 1969; Wingfield, Lindfield & Kahana, 1998). The general approach of the associative memory is that it enables encoding of associative information among the components of an episode (Naveh-Benjamin, Guez & Marom, 2003).

2.7 Strategies elaborated in verbal encoding and the interface between working memory and long-term memory

Verbal short-term memory has traditionally been perceived as relying on phonological encoding/phonological strategies and maintenance of representations. Furthermore, it has long been apparent that semantic encoding is also present during working memory processes, significantly facilitating immediate recall of verbal information. This concept has mainly been supported by studies investigating the semantic similarity effect. The interpretation of semantic encoding in working memory is therefore based primarily on two theoretical approaches. The first is the multicomponent working memory framework (Baddeley, 2000) proposing that the episodic buffer provides a link between long-term and working memory, accounting for the short-term effects of semantic encoding. The second approach is based on neuropsychological research, indicating a separate semantic buffer within working memory. However, only a few studies have manipulated the encoding and recalling strategies (phonological or semantic) during working memory tasks. These studies can be divided into two blocks. Within the first

block we can allocate studies manipulating the switch between phonological and semantic strategies. The second block contains the exploration of automatic versus controlled strategies elaborated during working memory tasks. In summary all of these studies suggest the selection of the most appropriate strategy in terms of the characteristics of processed items and the conditions under which processes are carried out (Campoy & Baddeley, 2008).

In particular, verbal information encoding in working memory tasks is a consequence of automatic and/or controlled attention demanding mechanisms of strategic retrieval and encoding (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Research into the retrieval of verbal items supports the distinction between a fast, automatic activation of mainly phonological or partially semantic representations and a slower, more controlled, and complex mechanism of deep semantic strategic retrieval (Badre & Wagner, 2002; Gold et al., 2006; Whitney, Grossman & Kircher, 2009). This notion, and the relevant research findings, indicate that in a range of working memory conditions automatic activation is not sufficient and a deep strategic retrieval is required. A few studies have shown that switching between phonological and semantic encoding and recall is possible and observable. It is reasonable to presume therefore that this distinction is applied to working memory and long-term memory, indicating that the creative strategies that underpin creative behaviour might have also a significant effect in encoding and recall processes.

The main reason for the existence of interpretation differences in verbal short-term memory relies on the adapted strategies, either phonological or semantic (Campoy & Baddeley, 2008). Although the use of a phonological strategy for recalling verbal information is considered predominant, under certain conditions or population characteristics the use of phonological strategy is partially abandoned in favour of a more reliable semantic strategy. There are a number of instances of theoretically important results in which major inconsistencies appear to have resulted from switching between phonological encoding and another strategy, probably semantic (Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996). For example, in groups of semantically unrelated words the most obvious and generally adopted strategy is a reliance on phonological encoding. In such situations automatic semantic activation is not possible and a controlled semantic strategic retrieval is not generally adopted. However, in groups of semantically related words it is very likely an automatic phonological strategy to be reduced or abandoned in favor of an automatic semantic strategic retrieval.

2.7.1 Switching between a phonological strategy and a semantic strategy

In regard to switching between a phonological strategy and a semantic strategy, significant findings have been reported by Logie, Della Sala, Laiacona, Chalmers and Wynn (1996). They requested participants to reflect (the participants were interveiwed) upon the strategies they employed in verbal short memory tasks. Where the participants reported the employment of a semantic strategy, the phonological effects were weaker in comparison to where the participants reported the adoption of a phonological strategy. The minimisation of phonological effects can therefore be interpreted on the basis of the adopted semantic strategy during encoding and recall. If we consider that the participants' reports reflect accurately the strategy they followed, then the reduction of phonological effects can indeed be attributed to this factor. It should be noted, however, that in this case, the semantic strategy does not only assist working memory task performance but fundamentally changes the gravity of phonological factors. The results of the study reflect the significance of semantic strategies and most importantly signify the importance of individual differences in working memory tasks procedures.

Hanley and Bakopoulou (2003) apply more direct manipulations in order to track the employed strategies in immediate serial recall of verbal information. Their manipulations allow a more detailed reflection of the strategy effects with regard to participants' performance in terms of irrelevant speech and phonological similarity. The general conclusion of the study indicates that the phonological similarity effect disappears due to participants' employment of a semantic rehearsal strategy. The authors stress that these findings are consistent with the findings of both Salamé and Baddeley (1986) and Baddeley (2000b). In particular, in their two experiments they divided the participants into three groups. The first group did not receive any instruction with regard to processing and retrieval strategies, while the second group was instructed to use a phonological strategy and the last group was asked to encode semantics (that is, to use each item as the initial letter of a word, instructing them to link the words to form a sentence). Hanley and Bakopoulou (2003) point out that their results are in conflict with Neath's (2000) feature model. Overall, the analysis of the results reveals the presence of a phonological similarity effect when phonological encoding is instructed but an absence of a phonological similarity effect in the group which were provided with semantic instructions. A further analysis of the control group indicates that for the participants employing a phonological strategy, the phonological similarity effect was present but it was not observed when a semantic strategy was employed. Finally, the

authors propose to repeat the same manipulations but with visual presentation of the stimuli, as done in the experiment of Surprenant, Le Compte and Neath (2000).

In relation to the effect of encoding and recall strategies in immediate serial recall Campoy and Baddeley (2008) conducted a study involving four experiments. Their main objective was to investigate and explain the theoretically important anomalous results in the area of verbal short-term memory by attributing these anomalies to differences in the employed strategies. In particular, they conducted four experiments involving the immediate serial recall of verbal item sequences. The main manipulation in all of the experiments was the instruction to use a phonological or semantic strategy. More analytically, there were three conditions; no instruction, phonological strategy instructions and semantic strategy instructions. In addition, two of the experiments varied phonological similarity while two manipulated word length. Overall, the analysis confirmed previous research (Hanley & Bakopoulou, 2003; Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996) indicating that the employed strategy and the strategy instructions do have significant effect on phonological similarity and word length effects.

In particular, the semantic strategy instruction group demonstrated elimination of the phonological similarity effect. In regard to the word length effect the results were complicated, allowing for different interpretations. The semantic strategy instruction group revealed a smaller word length effect in comparison to the phonologically instructed group. Therefore, phonological coding effects seem to be diminished as the length of the items increases. However, in semantic encoding the word length effect does not have a significant impact (the effect was marginal). This tendency can be attributed to the abandonment of a phonological strategy in the condition of semantic encoding (Baddeley & Larsen, 2007). However, an alternative interpretation may involve the idea that longer length items overload the phonological loop, rendering phonological encoding unhelpful regardless of strategy.

Another finding of the study is the presentation rate. Slower presentation rates allow the employment of a greater variety of strategies. Therefore, some participants choose to use a phonological strategy and they use the advantage of slow presentation rates while others adopts a semantic strategy and they are benefited by high presentation rates. This observation raises questions over the significance of individual differences in terms of the employed strategies in working memory. As creativity indicates the multiple use of strategies generally, this idea allows us to hypothesise that there is a

dynamic relationship between working memory strategies and creativity. Campoy and Baddeley conclude that the findings of the study "provide preliminary support for the argument that differences in strategy may underpin some of the apparent differences in empirical findings within the field" (2008, p. 338)

In summary, the studies conducted by Campoy and Baddeley (2008), Hanley and Bakopoulou (2003), and Logie, Della Sala, Laiacona, Chalmers and Wynn (1996) clearly indicate that the switch between phonological and semantic strategies is a standard phenomenon in verbal short-term memory tasks. The ability of a subject to switch relies on the characteristics of the task and on the instructions and the individual differences among the participants. It is apparent that a closer examination of the employed strategies during working memory tasks is a significant factor that could affect, positively or negatively, not only the performance but also more importantly the quality of the working memory process outcome. It is therefore important to further investigate the hypothesis of how the switch between phonological and semantic strategies effects the organization of long-term memory representations, especially if we consider the significance of the collaboration between long-term memory and working memory. Furthermore, a distinction between automatic and controlled strategies has to be investigated and evaluated. However, to date there are only a few studies targeting either the effects of switching between phonological and semantic strategies or the distinction between automatic and controlled strategies.

2.7.2 Automatic versus controlled strategies in working memory encoding

There are specific indications that semantic encoding in working memory tasks may rely on strategic mechanisms, either automatic or controlled. Automatic activation of semantic or phonological representations is observed, especially in situations such as tasks containing groups of semantically related words. However, in groups of semantically unrelated words a slower, more controlled, and mechanism of semantic strategic retrieval requiring effort is needed in support of the typical phonologically based strategy. This last is a situation in which automatic semantic activation is not sufficient and a controlled semantic strategic retrieval is required to support the typical phonologically based strategy. In other words, in this case the most obvious and generally adopted strategy is a reliance on phonological encoding. Moreover, according to the multicomponent model of working memory, phonological encoding is the main and relatively automatic mechanism in verbal short-term memory. The absence of contextual semantic support characterises standard working memory tasks involving the

presentation of lists of unrelated words. Therefore, semantic encoding in working memory tasks can rely either on strategic time dependent mechanisms or on standard mainly phonological retrieval.

In support of the notion that groups of semantically unrelated words require controlled semantic retrieval strategies, neuropsychological studies reveal that patients with lesions in the left inferior prefrontal cortex do not show semantic effects in working memory tasks (Martin, 2005). This brain region has been associated with top-down control of semantic memory, including controlled semantic retrieval and post-retrieval selection. Therefore, since these patients demonstrate disruption in mechanisms of control of semantic retrieval we can easily conclude that semantic encoding in working memory tasks relies mainly on controlled processes. In other words, this kind of patient has semantic working memory deficits due to disruption in mechanisms of control relating to semantic retrieval (Badre, Poldrack, PareBlagoev, Insler & Wagner, 2005; Badre & Wagner, 2002; Wagner, Paré-Blagoev, Clark & Poldrack, 2001; Whitney, Kirk, O'Sullivan, Lambon Ralph & Jefferies, 2011).

A further step involving the role of controlled mechanisms in verbal short-term memory tasks is the possibility that participants engage in elaborative strategies of semantic encoding in order to improve their performance. Such semantic strategies could involve, for example, the establishment of semantic links between words and the generation of stories or visual scenes. Evidence for the importance of these strategies of elaborative encoding emerges from studies showing that the adoption of this kind of semantic strategy eliminates the phonological effects usually considered the hallmark of verbal short-term memory, such as the word length effect or the phonological similarity effect (Campoy & Baddeley, 2008; Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996).

Whitney, Grossman and Kircher's (2009) study tests the hypothesis of two distinctive neural networks engaged in semantic encoding and retrieval. In particular, meaning retrieval of a word can proceed either quickly and effortlessly or can be characterised by a controlled search for candidate lexical items and a subsequent selection process. Their study reveals that meaning retrieval in context is supported by two neural networks, which are spatially distinct and hold different functional properties. The frontoparietal network seems to support bottom-up related retrieval processes and is based on brain regions that have been linked to semantic integration, universal attention and working memory functions. In other words, this process is

characterised as automatic. In contrast, the top-down control seems to be more restricted to structures of executive semantic processing and is particularly sensitive to different kinds of retrieval manipulations (that is, controlled versus automatic retrieval). For a successful recovery of meaning, a flexible adjustment of top-down and bottom-up regulation is required. The authors conclude that the recovery of meaning can be manipulated by the contextual environment. However, analysis of the results does not provide any information about individual differences, leaving space for assumption of different employed strategies according to a controlled decision process.

Hoffman, Jefferies and Ralph (2011) performed four experiments recruiting patients with apparently selective short-term memory deficits for semantic information. The aim of their experiment was to support the idea that:

> semantic STM deficits are not as selective as previously thought and can occur as a result of mild disruption to semantic control processes, i.e., mechanisms that bias semantic processing towards task-relevant aspects of knowledge and away from irrelevant information (Hoffman, Jefferies & Ralph, 2011, p. 368).

They assumed that strongly semantic similar words activate similar semantic representations in long-term memory. Therefore, a semantic relationship is established with little need for controlled processing. On the other hand, in cases where the association is weaker, a strategy with greater control is required in order to activate the relevant shared attributes and consequently to establish any potential relationship between the items. This tendency is linked to a requirement for a more controlled, flexible access to semantic knowledge than in cases where the criterion of category membership is apparent or commonly established.

In terms of the investigation of the effects of conditions requiring more semantic control in working memory special interest must be paid to the fourth experiment, which aimed to detect weak semantic associations. In this experiment patients and a control group were presented with a list of verbal items followed by a probe. They had to verify whether the probe belonged to the same semantic category as any of the list items. The main hypothesis was that list length would be the main determinant of performance, since a reduction in the capacity of the semantic buffer (Larigauderie, Michaud & Vicente, 2011; Haarmann & Usher, 2001) would affect the patients' memory for long lists. In contrast, semantic distance should have had a strong effect on performance. The results reveal that the patients were more affected by the semantic distance manipulation than the controlled group. In general terms, patients were

impaired with regard to semantic control in the standard probe verification task. They performed much better when the probe and target were very similar or when there was no relationship present. This indicates that the critical factor influencing the patients' semantic working memory deficits was not the amount of semantic information they had to retain but rather the cognitive control demands of performing the necessary semantic judgments. The authors suggest that the participants performed the working memory task on the basis of a semantic similarity strategy. However, it was possible for the participants to generate the category label for each item as it was presented and then compare their memory for the categories (rather than the items themselves) to the category label for the probe. The patients demonstrated robust effects of semantic distance while the control group showed much smaller but similar effects.

Jefferies, Frankish and Lambon Ralph (2006) recruited semantic dementia patients and tested them in terms of their immediate item recall with regard to lists comprised of words, non words and mixed words and non words. The analysis reveals that when participants attempt to recall lists composed of an unpredictable mixture of words and non words, a considerable number of phonological errors occur for words as well as for non words. In addition, word recall declines as the number of non words increases because word phonemes are more likely to migrate between list items or be recalled incorrectly. There was also an observable advantage for words versus non words, indicating the importance of strategic factors in binding/redintegration. The poorer recall of words in mixed lists relative to pure lists may have arisen due to a loss of knowledge about lexical status. Overall, the results suggest that knowledge of lexical status is used strategically to constrain output for pure word lists. However, Jefferies, Frankish and Lambon Ralph (2006, p. 94) point out that the factor of predictability and unpredictability in mixed lists could affect "how an item specific redintegration mechanism could discriminate between the degraded traces of words, which need to be lexically reconstructed, and the phonological traces of non words, which do not".

Following the findings of Jefferies, Frankish and Lambon Ralph (2006), Jefferies, Frankish and Noble (2009) conducted a study comparing lists of words, non words and mixed lists (lists compounded of words and non words). These lists were characterised either by a predictable, alternating structure (for example, a word followed by a non word) or an unpredictable sequence (that is, the serial positions of the words/non words could not be known in advance). The main aim of the study was to investigate "the extent to which the contribution of lexical/semantic representations is under strategic

control (that is, dependent on knowledge of the lexical status of the items)" (Jefferies, Frankish and Noble, 2009, p. 1968). The authors base their assumptions on Martin & Saffran' (1997) persepective that there is no distinction between the phonological representations that underpin working memory and language processing, but that there is an interactive activation between phonological, lexical and semantic nodes.

The analysis reveals that participants produce real word errors for words in mixed lists when they knew the lexical status of items beforehand. Additionally, this tendency was not observed in non words lists. This indicates that in mixed lists they employ a strategy for redintegrating items according to their lexical status. However, in non words lists they presumably deliberately avoid this strategy as they know this will cause mistakes. In addition, the participants were shown to be more accurate, making fewer phoneme migration mistakes in recalling words in lists containing only words than in non words lists or mixed lists. However, there was no difference in mixed lists between words and non words. These findings indicate that incorrect phonemes are avoided when participants are aware that the items are words. Furthermore, the absence of difference between the two types of mixed lists (predictable and unpredictable) in incorrect phoneme migration indicates the elaboration of an automatic phonological strategy and that there is a non controlled strategic binding. This notion is supported by the finding that mixing lists negatively affects the phonological integrity of words regardless of whether the structure of the mixed lists was available beforehand. In summary, the study indicates that lexical/semantic knowledge might be underpinned by several mechanisms, some of which are dependent on knowledge of lexical status and some of which operate more automatically. Consequently, semantic knowledge may contribute to verbal short-term memory via more than one mechanism.

Fournier-Vicente, Larigauderie and Gaonac'h (2008) examine the separability of six executive functions (verbal storage-and-processing coordination, visuo-spatial storage-and-processing coordination, dual-task coordination, strategic retrieval, selective attention, and shifting) and their relationships. Their aim was mainly to explore how executive functions interact in regard to the central executive system. One important element of the study was strategic retrieval and its relationship to shifting strategies and selective attention. Strategic retrieval refers to the ability to prevent inappropriate information from interfering with the retrieval of appropriate information from long-term memory. In particular, strategic retrieval is an active memory search as well as an active suppression of information. This information might be automatically

activated but its presence is irrelevant for the specific task or it may interfere with the current strategic search and retrieval operations. Shifting indicates the ability to suppress a response strategy or a mental set that has become inappropriate when shifting back and forth between multiple tasks, operations or mental sets. Finally, selective attention indicates the ability to prevent information that is irrelevant to the task from interfering with the selection of the target information.

The analysis reveals that these abilities, although moderately correlated, are distinct from one another. This indicates that different abilities may fulfill an inhibitory function depending on the task contexts. However, further research is required in order to investigate the effect of individual differences on the correlation of the aforementioned abilities. Soto, Hodsoll, Rotshtein and Humphreys (2008) provide evidence of the importance of the task, suggesting that the controlled strategies could be affected by other factors as well. In summary, Fournier-Vicente, Larigauderie and Gaonac'h's (2008) study reveals that strategic long-term memory retrieval processes and many other complex executive constructs can undoubtedly be identified and partially placed under one function, that is, the central executive.

Watkins, Kim and Le Compte (2000) carried out three experiments in order to compare the immediate serial recall of high- and low-frequency words, as well as words and non words in pure and alternating lists. The experimental manipulation was based on study strategies and specifically on what effects are observed when subjects are discouraged from adopting or introducing a strategy. Overall the results reveal that effect of word familiarity, and indeed whether familiarity is varied within or between lists, derives from the participants' strategy of favouring the non familiar words when studying mixed lists. Furthermore, this effect decreased as the strategy was restricted. The authors explain their findings by introducing the idea of the extent of processing "perhaps the rare words are thought about more deeply or for a longer time than the common words" (Watkins, Kim & Le Compte, 2000, p. 244). They propose that the strategies which facilitate recall of the non familiar words have an effect only in free recall and not in word recognition tasks. They conclude that this is less plausible because recognising is typically faster than recall and hence less open to introspection. Another possible explanation is that the subjects do not know how to adjust their strategies appropriately in similar tasks. Finally, Watkins, Kim & Le Compte, (2000) propose that the role of a participant's strategy might better appear in conditions other than those concerning the familiarity of an item. In summary, the study reveals that

familiar items demonstrate an advantage in free recall over non familiar items irrespective of whether the familiar and non familiar items are presented in separate lists or mixed in the same list. However, this advantage is eliminated when strong measures are taken to control the way the words are studied (p. 244) indicating that this is a consequence of a study strategy.

Soto, Hodsoll, Rotshtein and Humphreys (2008) rely on literature indicating that there are interactions between the process of keeping information "online" in working memory, and the processes that select relevant information for a response. Using fMRI techniques they argue that a high cognitive load might automatically lead to a degradation of the items held in working memory, as a result of increased inter-item competition for limited resources. When representations compete in working memory (under high load conditions), any strategy to ignore items that match stimuli in working memory might be helped because degraded representations might be more easily inhibited. These findings, however, are not in line with previous research indicating that the relevant working memory effects on item selection are as a result of participants attending strategically to any re-appearance of the working memory item in the search display in order to improve their working memory. Nevertheless, such findings do indicate that the use of controlled strategies in working memory could be affected by the characteristics of the task.

Campoy, Castellà, Provencio, Hitch and Baddeley (2015) hypothesise that in specific tasks semantic encoding is not a consequence of controlled, attention demanding processes of strategic semantic retrieval and encoding. Their hypothesis was tested in conjunction of the presence of the concreteness effect. Since controlled semantic retrieval and elaborative encoding are most probably time dependent, the strategic hypothesis predicts larger semantic effects when the to-be-remembered words are presented at slower presentation rates. The study involved three interrelated experiments. Although the first experiment revealed different results to the other two, the authors still conclude that semantic effects in working memory are revealed only from automatic semantic encoding strategies. However, this hypothesis was based on observations under concreteness effect manipulations and therefore any general conclusions for semantic encoding must be considered as overgeneralisations because encoding in working memory is highly task dependent (Nusbaum & Silvia, 2011).

Furthermore, the effect of employed strategies, either automatic or controlled is also determined by individual differences effects (Gilhooly, Fioratou, Anthony &

Wynn, 2007). In particular, the first experiment indicated that the presentation rate positively affected performance. This finding suggests that strategic, time-dependent semantic encoding benefits from the presentation rate, allowing the assumption of the presence of controlled strategies in working memory. However, this assumption was not applied in the other two experiments as the introduction of three different concurrent attention demanding tasks minmised any possible effects due to the strategic hypothesis. The results were explained by Campoy, Castellà, Provencio, Hitch & Baddeley (2015) as a negative effect of limited available attention resources on concurrent tasks related to general memory performance. However, this interpretation explains only the poor performance of the assumed controlled strategies and does not provide strong support for the assumed absence of controlled strategies, which would allow for alternative explanations. In relation to the present study the authors conclude that the findings of the first experiment indicate that:

> the participation of semantic codes in standard STM tasks (those involving the immediate serial recall of lists of unrelated words) relies on controlled, strategic mechanisms of semantic retrieval and elaborative encoding (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015, p. 772).

Overall, although the authors propose an automatic semantic encoding approach they conclude that:

> the present study shows that semantic encoding in standard verbal short-term memory tasks (immediate serial recall of unrelated words) does not depend on the participation of controlled semantic strategies. It is important to note, however, that this does not mean that participants cannot implement this kind of strategy in certain circumstances, as suggested by the fact that the standard phonological effect in STM is abolished when participants are explicitly instructed to use a semantic strategy (Campoy & Baddeley, 2008) (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015, p. 775).

The findings of research into divided attention indicate that the encoding process requires attention and this is under the subject's conscious control (Naveh-Benjamin, Guez & Maron, 2003). Recently, neuroimaging studies (Anderson, Bjork & Bjork, 2000) have revealed that divided attention at encoding reduces encoding related brain activity in the left inferior prefrontal cortex. This is an area shown in other studies to be associated with deep strategic semantic processing, indicating that divided attention could affect deep strategic semantic processing. In other words, divided attention at

encoding changes the qualitative nature of encoding so that it becomes less semantic. However, recent studies into memory have provided different results.

In Craik and Kester (2000), subjects were tested on connection with item pairs. Results indicate that, in contrast to what is predicted by the elaboration of the processing hypothesis, for the same degree of strategic semantic elaboration, fewer words were recalled after being encoded under divided attention conditions. This implies that there is a mechanism other than the degree of strategic elaboration underlying the effects of divided attention at encoding on later memory performance. In addition, Naveh-Benjamin, Guez and Marom (2003) argue that the effects of divided attention at encoding are similar when learning is incidental and no deep level strategic processing is used as well as when learning is intentional and deep elaborative strategies are used. These findings indicate that controlled strategies could operate irrespective of the negative or positive effects of automatic mechanisms, or even effects such as divided attention.

In relation to the debate over the employment of automatic and controlled strategies in immediate free recall, a study conducted by Engle, Tuholski, Laughlin and Conway (1999) is highly related as it indicates the dichotomy between automatic and controlled processes. They tested 133 subjects in 11 memory tasks,,seeking to evaluate working memory and short-term memory. The structural equation modelling analysis reveals that working memory and short-term memory are separate but highly related constructs suggesting that many working memory tests used in scholarship may well have measured not only working memory performance but also short-term memory performance. However, according to the multicomponent model of Baddeley the distinction between those two constructs relies on different levels of processing of the same structure. Furthermore, the proposed dichotomy between working memory and short-term memory could reflect the applied different strategies that are used in different tasks. This argument is supported by the authors' suggestion that the verbal short-term memory performance is explained by working memory capacity, indicating that the applied strategies, mainly controlled, in working memory have a significant effect on immediate serial recall tasks of verbal information (Engle, Tuholski, Laughlin and Conway, 1999). The authors go on to explain the relationship indirectly, indicating that both rely on controlled attention mechanisms and functions of prefrontal cortex. This area is related to fluid intelligence and thus to both working memory and short-term memory. However, the area is also related to creativity, establishing no direct

causation between creativity and working memory but rather allowing the assumption of a main involvement of strategies on working memory.

2.7.4 Summary

In summary, the literature provides stable indications to assume that semantic encoding in working memory tasks could rely on strategic mechanisms, either automatic or controlled. However, there are contradictions over the question of which type of strategy is applied in specific tasks and their effect gravity as well. These dichotomies are mainly derived due to the different characteristics of the measurement methods. As Miyake, Friedman, Emerson, Witzki, Howerter and Wager (2000) point out, the evaluation of the employed strategies on working memory tasks has specific weaknesses derived mainly from the individual differences spectrum. They underpin the existence of differences in terms of the employed strategies not only between subjects but also within the same subjects, as much as not only on different tasks but even within the same task.

> Complex executive tasks tend to suffer from relatively low internal and/or test–retest reliability. Although the reasons for the low reliabilities are not completely clear, one possibility is that people adopt different strategies on different occasions (or even within a session) when performing these tasks. Also, the involvement of executive control functions is generally considered strongest when the task is novel (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000, p. 53).

Such findings indicate that the use of automatic or controlled strategies in working memory can rely not only on the characteristics of the task but also, more importantly, on relevant individual differences factors.

2.8 Phenomena and hypotheses related to semantic encoding and the interface between working memory and long-term memory

The interface between working memory and long-term memory must be approached in relation to specific phenomena and hypotheses: the “chunking hypothesis”; the “semantic clustering effect” and studies related to “associative memory” (Poirier & Saint-Aubin, 1995). All of these indicate that semantic encoding in working memory tasks places some reliance on strategic mechanisms. Significant data for these strategies can be extracted from both the chunking hypothesis and clustering effect.

2.8.1 Chunking hypothesis

Baddeley (2007) suggests that the advantage of semantically similar over dissimilar words in working memory stems from specific differences with regard to subjects binding together individual words. This process is called chunking. Chunking is an effective form of strategic encoding that involves the processing and thus the recoding of a set of data into a more compressed, efficient form. This encoding can eventually extend working memory capacity. Decades ago Miller (1956) demonstrated the importance of chunking in terms of short-term memory capacity. Miller's (1956) suggestion was that working memory capacity does not rely on the number of processed items but rather the number of chunks. Although this suggestion was very influential at the time, the initial research did not attempt to explicitly capture information binding. More recent research has provided findings allowing for a more precise understanding of processes requiring chunking. The most significant difference when we compare the present studies with Miller's suggestion is the now accepted position, supported by Baddeley, that chunking is not only an exclusive process of long-term memory representation but rather that some processes and systems can be utilised in working memory (Baddeley, 2007).

A relatively different approach to Baddeley's has been developed by Cowan (2000). He defines the term "chunk" as a collection of concepts that have strong associations to one another and much weaker associations to other chunks concurrently in use. Although Baddeley and Cowan's approaches interpret the phenomenon on relatively similar functional grounds, they do have different principles in regard to their structural concepts. The most significant difference between the two is located in their views on the collaboration between working memory and long-term memory. According to Baddeley's model working memory and long-term memory are distinctive dimensions of memory. However, his model allows for dynamic collaboration. This is mainly achieved through the episodic buffer. While Cowan and Chen (2009) do accept the episodic buffer as a reasonable explanation for collaboration between working memory and long-term memory, Cowan (2000) also supports the notion of a less distinctive division of memory into working and long-term. His approach argues that information in working memory can be conceived of as the activated portion of long-term memory. This works because of the ability of the episodic buffer to activate long-term memory representations. Therefore, chunking formation is achieved by the mutual collaboration of long-term representations and working memory processes.

The classical example of Miller (1956) can be used initially to explain the process. Suppose the subject is asked to recall a sequence of letters, "f b i c b s i b m i r s". According to the subject's capacities letter triads within this sequence (FBI, CBS, IBM, and IRS) may be identified and therefore encoded and recalled. Of course this identification requires pre-existing associations between the acronyms in long-term memory. If this is not the case, then recall of the sequence will have to rely on separate storage in working memory. It is possible that no other mnemonic strategy exists and therefore recall will not be assisted. This procedure is based on intra-chunk associations and weak inter-chunk associations. It has been shown that subjects group items in memory by employing a variety of different cues, including perceptual similarity, semantic relatedness, and statistical co-occurrences between items (Cowan & Chen, 2009; Fournier-Vicente, Larigauderie & Gaonac'h, 2008; Cowan, 2000). However, words from the same semantic category are not automatically grouped into a chunk. The level of association between the presented items varies according to categorical variations and individual differences. A similar idea states that even if the subject does not use the share of the same semantic category within the items as a supporting cue, the associations between items are enough to induce subjects to hold all the items from a category in mind independently. However, this does also imply that the subject manages to create sub categories.

Miller (1956) proposed that the ultimate number of items that can be grouped into a chunk is seven. This number also affects how these chunks are stored in long-term memory. Several investigators have since shown that short-term memory performance is best when items are grouped into sub lists of no more than three or four. Apart from this ability to form chunks out of a number of items, subjects are also reported as having the ability to group the chunks together to form "supergroups". Scholarship reveals that this grouping limit is three to five items. This limit to the grouping process makes sense when we consider that the items or groups to be further grouped together must reside in a common, central workspace so that they can be linked. Therefore, it is essential to assume a hierarchical grouping structure. Further to this, the focus of attention, the presumed locus of limited capacity storage, presumably must also be able to shift back and forth from the supergroup to the group level.

With regard to Cowan's model it can be said that it underestimates the capacity of working memory to combine and manipulate information in novel and creative ways. Instead, it proposes that the activated representations in long-term memory are only

maintained in a temporary store. This idea necessarily underestimates the contribution of the episodic buffer in the process of combining the information. In other words, the main problem is located in the need for the inclusion of new associative processes within working memory as these associations cannot exist in long-term memory per se. This notion was moderated in a study conducted by Chekaf, Cowan and Mathy (2016).

In relation to the procedure for chunk formation, Chekaf, Cowan and Mathy (2016) developed an innovative approach underpinning the "the capacity of immediate memory to cope with new situations in relation to the compressibility of information likely to allow the formation of chunks" (p. 96). The idea that subjects have the tendency to retain information by recoding it into chunks is not questioned in scholarship. The process of chunking simplifies memorisation by taking advantage of knowledge to reduce the quantity of information to be retained. As a key learning mechanism, chunking has been investigated mainly with regard to the collaboration of long-term stable chunks and their influence on working memory. However, Chekaf, Cowan and Mathy (2016) have now provided "a principled quantitative approach to how immediate memory relates to the formation of chunks" (p. 97).

This theory is a two factor theory relating to the formation of chunks in immediate memory. The two factors are the "compressibility" and "the order of the information to memorize". Compressibility refers to the process of recoding information by a compression process without loss of information: the original information is merely reconstructed in compressed form but not reduced. The chunking process can then be further activated resulting in a more substantial reduction of data. This process of chunking is achieved by patterning and simplifying data. Thus, memory for compressible sequences of items is superior to memory for non compressible sequences.

The second factor relating to this theory is the order of information to be memorised. The presentation order of the items can affect, either positively or negatively, the discovery of patterns and regularities, and consequently the dependant compression algorithms. In general terms, therefore, the simplifying processes rely on the order of the to-be-remembered or processed information in order to increase the likelihood that chunking occurs. If the order of information does not act to facilitate then these simplifying processes might well result in a failure to chunk compressible materials, causing items to be remembered in a way similar to non-compressible materials. This alternative view allows for the incorporation of additional factors in working memory. However, these factors obviously cannot be totally articulated here.

For example, creativity and the underlying processes of creative cognition could also provide additional data and support for the procedures of chunk formation in working memory.

The two factor theory is supported to some extent by the findings of Chekaf, Cown and Mathy (2016). They propose that chunks should not be perceived only as a result of permanent groupings of information in long-term memory. The results of this study further allow us to assume that subjects can spontaneously compress information without much mediation of long-term memory chunks. Information can be compressed in a few seconds in working memory by capitalising on the regularities within the presented items.

In this study the stimuli were categorisable multidimensional objects, with discrete features such as shape, size and colour. They included, among other shapes and colors, small green spirals, large green spirals, both small and large black and white squares and triangles, as well as small red squares. Each sequence potentially represented a specific pattern (for example, large white square, large black square, small white square, small black square, small white triangle, and small black triangle). The sequences did not conform to already learned chunks, although the basic characteristics of each object were considered to be basic knowledge. In terms of compression the sequence cited above can be redescribed accurately by a shorter logical rule provided that order does not matter: “squares or small”, using inclusive disjunction, or “not [large and triangle]” using conjunction, which by de Morgan’s law are equivalent. Another example is the sequence, “small black square, small black triangle, small white square, small white triangle”, which can be simplified by abstracting the feature common to the four objects: “small” (Chekaf, Cowan & Mathy, 2016). Here we can see how the information for this category is even more compressible and does not require much mental effort to be retained. Therefore, the independent factor is the level of compressibility of the information.

The analysis of the study reveals four main findings:

(1) Recall performance depends on sequence length to the extent that longer sequences require a representation with more chunks.

(2) A higher compressibility of information results in better recall because higher compressibility enables better recoding of the entire set of items.

(3) A greater degree of regularity in the presentation order (rule-based, followed by similarity-based, followed by dissimilarity-based) favors the compression of the available regularities into newly formed chunks.

(4) In relation to presentation time, a better recall performance was observed for the longer duration presentation.

Gobet and Clarkson (2004), in an alternative study on chunking, demonstrate that expert chess players more accurately remember the locations of more pieces on a chessboard than novice players. However, this is only when the pieces are arranged as if in an actual chess game. The expert chess players here are clearly recognising and recalling meaningful configurations of pieces before breaking them into parts demonstrating how it is possible to recall and process large relations among individual items in working memory. In other words, the expert chess players create chunks in order to expand the total number of items remembered over a brief period of time, although significantly only when these chunks are meaningful. Gobet and Clarkson (2004) further argue that rapid encoding in long-term memory can only be observed when the parts or positions belong to a meaningful state according to the rules of the game or the knowledge of the subject.

Following this line of thought Freyhoff, Gruber and Ziegler (1992) also tested chunking in relation to chess players. Participants were asked to divide chess positions into groups that were only meaningful to them. Subsequently, they had to combine these groups into both larger and smaller groups. The analysis reveals that expert players were able to incorporate larger amounts of pieces into groups/chunks at all three conditions of the experiment. In addition, the amount of pieces grouped successfully increased as the positions of the pieces became more meaningful. These findings thus support the assumption that chunk formation and indeed the size of each individual chunk are dependent on individual differences among the subjects. Understanding that expert chess players are likely to score highly in terms of creative ability it is therefore reasonable to suggest a relationship between creativity and chunk formation or working memory processes.

Further research in this area reveals the effect of stimuli interfering between presentation and recall of chess positions. This suggests a tendency towards rapid storage in long-term memory. According to the classic view of chunking theory, in a recall task, learning is supposed to be slow and information is only encoded in working memory. These findings have since triggered the development of a revised theory of

chunking by Gobet and Simon (1996) suggesting that chunks, and presumably sub chunks, can be indexed using a hierarchical discrimination network. Chunks are also seen as developing into higher-level structures (templates) with slots allowing for rapid long-term memory encoding. This interpretation allows for certain tendencies in long-term memory structuring to affect working memory processes. Some of these tendencies, it is reasonable to assume, must be connected to creativity.

2.8.2 Clustering effect

Another phenomenon that is related to the semantic similarity effect is semantic clustering. Under the term "clustering" we can include the recall of an item after the presentation of a semantically similar item. Manning and Kahana (2012) provide the following definition "recall of a given item is more likely to be followed by recall of a similar or related item than a dissimilar one" (p. 511). In other words, when two semantically related words (for example, teacher–student) are presented together, those words have more chance of being recalled successively in contrast to a pair of non semantically related words.

Various attempts have been made to estimate the relevant relatedness of individual items. However, accurate estimation is a matter of some difficulty. Manning and Kahana (2012) argue that "measuring semantic clustering requires making assumptions about what each word means to each participant" (p. 512). It is therefore reasonable to suggest that such assumptions must include the possibility of methodological mistakes being made. For example, the words "student" and "class" can be considered as a typical pair in terms of the clustering effect. Yet they may also be determined as non related when considered under a clustering effect that uses different boundaries. For example, "students" fall under the category of "alive" whereas "class" belongs under the category of "inanimate object". Thus it is very difficult to establish semantic associations when terms are highly affected by subjective experiences. In addition, the participants in a study may use a semantic similarity model that is different to the scoring model of the experiment. Many applied scoring techniques are highly sensitive to the specific structure of the experiment and more importantly to the applied statistical analysis that will be followed (Manning & Kahana, 2012).

A few techniques have been developed in order to estimate the relevant relatedness of items: the latent semantic analysis; the Google similarity distance; and word association spaces.

Manning and Kahana (2012) suggest that: “these concerns raise questions over the appropriate estimation of all the involved factors. Significant factors such as creativity might be left unobserved and unexplored” (p. 514). Perhaps more importantly for this thesis, Manning and Kahana (2012) indicate that the factor of semantic similarity or semantic relatedness has a large effect on the number of correctly recalled items. However, their research also indicates that there is no significant interaction between the factor of semantic similarity and the trials suggesting that the semantic similarity effect is in fact not sensitive to the experimental manipulations. This allows for the assumption that other factors such as creativity might significantly correlate with the factor of semantic similarity.

3. Creativity

3.1 Terminology

There are many definitions of creativity. For some, creativity is the ability to bring something new into existence, while for others it is not an ability at all but rather a psychological process. According to other definitions the notion of ability does exist but is connected to creativity in an indirect way (for example, the ability to work on the basis of a specific process). Finally, for others, creativity is not a process at all, but simply a product. Definitions of creativity also range all the way from the notion that it merely involves simple problem solving to conceiving of it as the full realisation and expression of the sum total of an individual's unique potentialities (Roslansky, 1970). Although creativity as only divergent thinking is also difficult to define (Rogers, 1970), for the purpose of this thesis the most accepted definition is the ability to produce work that is both novel (that is, original or unexpected) and appropriate (that is, useful or adaptive within task constraints) (Sternberg, 2003).

In terms of scholarship, there are numerous and varied definitions of creativity. For example, see Kampylis, Berki & Saariluoma, 2009; Zeng, Proctor & Salvendy, 2011; and Sternberg, 2003 to list but a few. Mayer's (1999) review of the seven different definitions provided by the authors contributing to the 1999 *Handbook of Creativity* (Sternberg, 2003) concludes that significant scholars in the area endorse the idea that creativity involves the creation of an original and useful product, including ideas as well as concrete objects. In particular, the product must be new and given value according to external criteria. The creative idea must be both original and appropriate for the situation in which it occurs. In summary, a more recent approach has stated that creativity is a process of producing original/novel and appropriate/valuable products within a specific context or area (Yeh, 2011). Other researchers approach creativity within the context of everyday activities. In particular, Simonton (2012) defines it as the ability to come up with novel and appropriate solutions to everyday problems, highlighting its adaptive nature. In general terms, most definitions of creativity rely on a series of specific notions or pillars. These can be identified as people, products and processes.

As can be seen above, each researcher appears to refine and adapt the basic definition of creativity according to their specific area of interest (Sternberg, 2003). While all of the above definitions have elements in common it is important not to lose sight of the differences. For example, the definition of creativity displays different

characteristics in western as opposed to eastern societies. Furthermore, over the past few decades, definitions of creativity have changed from being one-dimensional, becoming multidimensional. They have also included elements from the affective domain (Csikszentmihalyi, 1999; Amabile, 1996; Sternberg & Lubart, 1996; Gardner, 1993).

In addition, creativity is a term that is necessarily linked to unpredictability, which adds to the level of complexity in attempting to offer something of a clear definition. The special characteristics of the phenomenon as well as the different methodological procedures used further complicate the issue. However, this reality does not preclude the growth of a promising scientific field (Sternberg, 1999). The fact that the literature in this field has not yet been able to settle on a clear definition of creativity, or indeed accurately describe creative thinking or the characteristics of creative production, does not indicate an absence of appropriate, qualitative research. While research into creativity is new within the field of humanistic and social sciences, and it is only within the last few decades that research has produced specific findings supported by effective and reliable scientific methodology, philosophers have for a long time been studying the concept and expressing their ideas.

The abovementioned difficulties in defining creative thinking and creative products are increased by a polyphony of approaches to this area of study. The use of a variety of different methodologies and starting points for researchers, may also responsible to some extent. Nevertheless, while many of these approaches seem to be completely different, they do in fact have some common elements and their main theoretical stance towards the phenomenon is almost the same (Sternberg, 2000). Sternberg (1999) points out that the majority of the work dealing with creativity relies on psychometric methods. Indeed, all current work on creativity can be said to be based upon methodologies that are either psychometric in nature or were developed in response to perceived weaknesses in creativity measurement. Almost all major twentieth century psychologists have taken creativity seriously and explored what it means to be creative (Sternberg, 1999). In addition, authors and researchers from a variety of backgrounds have published a significant amount of books and articles on the topic of creativity (Ambrose, Cohen & Tannenbaum, 2003).

Creativity is, indeed, a multi faceted phenomenon. With the wealth and volume of this body of scholarship, from a variety of different disciplines, it is therefore difficult to choose the best single definition of creativity. Indeed, such is the nature of creativity

that it carries all of these meanings and many more besides (Roslansky, 1970). Nevertheless, as mentioned above, within the scientific area of creativity research there two approaches that are of special interest and have relevant application to this area of study. In particular, psychometric approaches are by definition important because the vast majority of prior studies into creativity have been based on this methodology, in its various forms. In addition, the investigation of creativity as a component of problem solving procedures offers a valuable contribution to our understanding of creativity, especially in emphasising the cognitive mechanisms that underpin creative processes and production.

3.2 Historical review of the research in "creativity"

3.2.1 Psychometrics and creativity

Within the psychometric tradition four specific areas in which psychometrics have been applied to creativity research can be identified. These areas include: investigations of creative processes; personality and behavioral correlates of creativity; characteristics of creative products; and attitudes of creativity within fostering environments. Today the creative process is recognised as a scientifically researchable area of study. Further, the creative person as considered capable of contributing to this research by providing information and experience much like all the other scientific areas of human and social studies.

It is misleading to refer to the creative process as single and unitary. It is instead a complex structure involving cognitive, motivational and emotional processes that are involved in perceiving, remembering, imaging, appreciating, thinking, planning, deciding and evaluating (Ambrose, Cohen & Tannenbaum, 2003). Such processes are found in all persons and not just in those few defined as "creative persons". However, there are wide differences in the quality of these processes as well as in the degree to which individuals can be characterised as creative. In terms of the creative process as related to problem solving, there are five distinguishable stages or phases outlined below:

(a) a period of preparation during which the individual acquires the elements of experience, the cognitive skills and the techniques which make possible full awareness of the problem;

(b) a period of concentrated effort in order to find an effective solution to the problematic situation — this phase may be fast and without delay or it may last for a longer period;

(c) a period of withdrawal from the problem — a psychological form of "taking a step back";

(d) a moment of insight that is potentially accompanied by exhilaration, often a flash moment or a unique experience that cannot be described with words;

(e) a period of verification, evaluation and application of the insight produced or experienced (Sternberg, 2003).

The second major area of psychometric research with regard to creativity involves attempts to identify factors associated with creative people. Studies in this area mainly concentrate on general correlation of creativity with other factors, specifically personality characteristics, which are mostly used to predict future creative behavior (Sternberg, 1999). Research indicates that factors such as past creative behavior (often assessed using a self report methodology) can be used to determine future creative potential and achievement. A further significant factor is tolerance. Tolerance for ambiguity is often mentioned as a personality characteristic of creative individuals (Sternberg, 1999). Additionally, theoretical and empirical supports exist for the connection between ideational attitudes and ideational thinking. However, this dimension of creative research is very limited and often avoids consideration of crucial factors necessary for the understanding of creativity. Indeed, it is mainly focused on attitude measures used to evaluate attitude interventions in a business context (Runco & Basadur, 1993). Finally, an interesting and fairly recent application of person oriented psychometric methods is the measurement of implicit theories of creativity as outlined by Sternberg (2000).

Perhaps the most important factor, and a starting point of all studies of creativity, is the definition of a creative product. This necessarily includes clarification of what makes creative products different from other products. In other words, what are the qualitative characteristics that make something exceptional and creative. The significance of creative products relevant to this research is located within a valid methodology. The establishment of objective external criteria over the description of creative products is essential in order to enable valid comparisons and effective experiments. However, such an absolute, safe and unquestionable criterion of creativity has not been defined in previous scholarship (as disucssed above) as a result of the

special nature of creative characteristics (Runco, 1989). Therefore, the recognition of a product as the result of a creativity process requires identification of a number of specific characteristics. Most researchers agree on two essential requirements.

1 A product must be novel. However, the novelty of a product is nevertheless affected by a number of factors such as the relationship of the product to other relevant products, the general characteristics of the investigated population and, indeed, the referent person (for example, the individual's age and their socioeconomic background). Implicit memory can also affect any evaluation of the creative product in terms of novelty.

2 The second requirement is that the product must be adaptive to reality. In other words, it must provide an efficient solution to a specific problem. The product must fit the needs of the given situation.

However, some researchers suggest that there are in fact more than two main criteria. For example, Roslansky (1970) includes a third criterion. He proposes that the product should create new conditions in terms of human existence. In order to be considered a creative product it must transcend and transform the generally accepted experience of the individual by introducing new principles that defy traditions and change peoples' view of the world and themselves.

Finally, another major area of psychometric research involves attempts to identify creative environments and investigate their interactions with the individual. These studies seek to determine environmental variables that are related to creative productivity, with the hope that measurements of the relevant factors will facilitate the design and implementation of environments that could promote creative achievement more efficiently. This hypothesis has its origins in the assumption that western society so far has constantly caused difficulties or even punished individuals for being creative or even expressing their ideas and uses as it's examples people such as Socrates or Galileo (Sternberg, 1999).

Of great importance to our understanding of the concept of creativity is Rogers' understanding of creativity. Rogers (1970) attempts to define the creative process with a definition that includes a dynamic quality as a basis for further theoretical and experimental work. According to Rogers, the creative process is

> the emergence in action of a novel relational product, growing out of the uniqueness of the individual on the one hand, and the materials, events, people, or circumstances of his

life on the other hand (Rogers, 1970, p. 71).

While this definition of the creative product does provide us with an initial basis from which to work, it does have some flaws. For example, there is no discrimination between "good" and "bad" for Roger's creative products. For both results the creative process is exactly the same. Any product of the creative process is always related to the society in which it is found and any successful creative product is almost always linked to the contemporary and central ideas of that society. In other words, the product must be acceptable to a particualr group at a particular point of time. Therefore, it is not possible for the concept of societal acceptance to be excluded from a general definition of creativity.

In addition, while Rogers proposes that it is essential for the relevant degree of creativity to be taken into consideration at all times, the reality is that this is not useful when placed into a "real world" scenario. For example, a child's invention of a new game and a scientist's new approach to a significant phenomenon cannot be evaluated using the same criteria. Further, for Rogers, research in the area of creativity is concentrated on the cognitive processes of creativity, the conditions under which these processes occur. Thus motivation is of great importance in the process of creativity. Important factors are the conditions under which the individual operates, that is:

(a) Openness to experience: instead of perceiving something through a stable cognitive category, the individual experiences it as it is. Everything is perceived as new with unique dynamic characteristics. This ability or tendency also requires tolerance for ambiguity as the individual perceives and uses conflicting information without eliminating any possibilities;

(b) An internal locus of evaluation: the individual evaluates their own judgments over the criticism of others; and

(c) The ability to manipulate elements and concepts: this is the ability to adjust ideas, elements and hypotheses. It is the ability to generate alternatives (Sternberg, 1999).

3.2.2 Creativity as a problem solving process

As mentioned above, over the last few decades, a multivariate approach to creativity has developed. As a result, any interpretation of creativity requires a particular combination of cognitive factors whose expression is influenced by environmental conditions. The nature of the proposed factors and their interaction varies according to different

theorists (Lubart, 2001; Feldhusen, 1995). For example, Amabile (1996) proposes a componential model in which creativity and creative processes derive from a particular set of skills, specifically: domain relevant skills (that is, knowledge that is both broad and specific); creativity relevant skills (that is, the ability to break, synthesise and reconstruct mental sets in order to create or conclude an idea that is innovative or efficient); and task motivation (that is, interest and commitment to find a solution or to overcome an obstacle). Using a similar approach Feldman, Csikszentmihalyi and Gardner (1994) develop a system approach that is oriented towards interactions between individuals (using their cognitive factors), domains (culturally defined bodies of specific knowledge) and fields (for example, specific people could potentially influence a specific field using their capabilities).

From the cognitive psychology perspective some information processing abilities are particularly important (Sternberg, 1999). Additionally, an individuals' knowledge nodes and cognitive styles play a significant role in problem solving situations and instances when they are required to produce a novel or innovative idea. The intellectual abilities that are considered essential can be summarised as the ability to:

- identify the problem to be solved;
- notice the environmental information in relation to the problem;
- selective encoding;
- observe similarities and differences between different fields that identify the problematic situation (analogy, metaphor);
- combine different elements, generating several ideas related to the situation; and
- constantly evaluate progress towards the efficient solution of the problematic situation.

Together these capabilities represent the fundamental elements of creative process. Some scholars refer to these as sub processes of general intelligence and they are also known as elements of synthetic intelligence and analytical intelligence. However, recent studies have come to recognise these abilities as essential parts of creative thinking and they are no longer perceived as intelligence specific characteristics (Cushen & Wiley, 2012; Storm, Angello & Bjork, 2011; Brophy, 2000).

3.3 Underlying cognitive mechanisms and processes of creative thinking and production: Divergent Thinking, Convergent Thinking and Associative Processing

Researchers studying the cognitive processes underpinning creativity have explored various phenomena. As a result, the main cognitive processes underpinning creativity have been identified as: associative thinking processes (Benedek, Konen & Neubauer, 2012); divergent thinking processes (Nusbaum & Silvia, 2011; Cho, Nijenhuis, Vianen, Kim & Lee, 2010); and convergent thinking processes (Brophy, 2000; Ward, Smith & Vaid, 1997; Finke, Ward & Smith, 1992). Furthermore, the relationship of creativity to executive functions has also been examined. However, this has previously been accomplished without testing this relationship with regard to the three cognitive processes underpinning creativity; associative, divergent and convergent thinking. Table 1 below offers a summary of the definitions of the main cognitive abilities underlying creative processing. It contains key definitions of divergent thinking, convergent thinking, and associative processing as found in contemporary scholarship.

Divergent thinking	Convergent thinking	Associative processing
Brainstorming (Osborn, 1953)	Synthesis and analytic ability; breaking down symbolic structures in perceptual and conceptual domains (Guilford, 1950)	Building connections between elements of associative networks (Mednick, 1962)
Generating many possibilities (Guilford, 1967)	Anticipating the functional characteristics of generated ideas (Guilford, 1967)	Ability to access and retrieve a broad range of elements (for example, words needed for a solution) by maintaining and bringing into continuity separate sequences of mental activity (Mendelsohn, 1976)
Goal-oriented reasoning in different directions that takes into account a variety of aspects (Dorner & Kreuzig, 1983)	Evaluation and selection of adaptive ideas (Sternberg, 1985)	Formation of uncommon associations as a result of defocused attention and lowered cognitive inhibition (Eysenck, 1995)
Idea generation phase of creative process (Finke, Ward & Smith, 1992)	Systematic reasoning directed towards on correct answer (Dorner & Kreuzig, 1983)	Ability to oscillate between primary (for example, analogical, free-associative) and secondary (for example, logical, analytic) processes (Martindale, 1995)
Unstructured thinking; spontaneous processes with multiple explanations (Finke,	Exploration phase; structured aspects of creative thinking that involves conscious deliberate	Involved in the ability to remember and voluntarily recall specific associations between

1996)	control (Finke, Ward & Smith, 1992)	stimuli (for example, learn multiple response-outcome contingencies) (Kaufman, Kaufman & Lichtenberger, 2011)
The nature of tests where going off in multiple directions to obtain multiple answers increases the scores (Goff & Torrance, 2002)	Problem solving that is goal-directed and requires a single correct answer (Runco, 2007)	Ability to fluidly retrieve and combine remote associations (Benedek, Konen & Neubauer, 2012)
Producing many different answers (Runco, 2007)	Working towards concrete goals (Nielson, Pickett, Simonton, 2008)	

Table 1. Summary of definitions of the main cognitive abilities underlying creative processing; divergent thinking, convergent thinking, and associative processing. From Kaufman, J. C., Kaufman, S. B. & Lichtenberger, E. O. (2011). Finding Creative Potential on Intelligence Tests via Divergent Production. *Canadian Journal of School Psychology, 26* (2), 83–106.

3.3.1 Divergent thinking as an underlying cognitive mechanism of creative production

Divergent thinking refers to a deductive process that involves systematically applying rules, organising ideas and evaluating options, in order to arrive at a single, correct solution (Kaufman, Kaufman & Lichtenberger, 2011; Brophy, 2000; Guilford, 1967). It is an important cognitive process associated with future creative achievement (Runco, 2010). However, it only indicates a part of creativity. Palmiero, Giacomo and Passafiume (2014) also argue that divergent thinking is an important cognitive process associated with future creative achievement. It is not the same as creativity, which requires transformations of thought, reinterpretation and freedom from functional fixedness (Guilford, 1960; 1962; 1986). In general terms, divergent thinking involves the ability to find many different and original solutions to problems and tasks (Guilford, 1967). It can thus be related to intelligence, as Guilford (1967) suggests. It can be scored in terms of fluency (the number of relevant ideas), originality (the number of infrequent ideas), flexibility (the number of category shifts in responses), and elaboration (the number of details of ideas).

In his classic book Guilford (1967) makes a clear distinction between divergent and convergent thinking while also classifying divergent thinking as a significant process of creativity. He describes what he terms “divergent production” as consisting of four specific abilities, as mentioned above: fluency, flexibility, originality and elaboration. A common test used to measure divergent production is the Unusual Uses

Test (Guilford, Merrifield & Wilson, 1958), in which participants are asked to list all the uses of a familiar object, such as a brick. In this context, fluency is measured by quantity, the number of responses, while flexibility is measured by the variety of different categories or concepts evoked. Elaboration is measured by the level of descriptiveness of each use and originality is measured by uniqueness of response in comparison to the other participants. Modern researchers use the more broad term "divergent thinking" to describe what Guilford referred to as divergent production. Other tests used to measure divergent thinking include the Torrance (1966) Tests of Creative Thinking (TTCT) and the Consequences Test (for example, "Imagine everyone lost the ability to read and write. What would happen as a consequence?"). The common characteristic of these tests is the necessity of providing as many answers as possible to specific problems.

Even though these tests were constructed in order to assess divergent thinking, "they provided and they were approached as a standardized method to gather and score creativity data" (Sternberg & Lubart, 1996, p. 861). Plucker and Runco (1998) reinforce this idea, stating: "psychometric studies of creativity conducted in the previous few decades form the foundation of current understandings of creativity" (p. 36).

Runco and Chand (1995), in their review of research on creativity, recognise three different tendencies in the relationship between divergent thinking and creativity. The first suggests that divergent thinking is synonymous with creative thinking. The second sees divergent thinking and creativity as totally opposed notions. Finally, the third tendency compromises the two previous approaches and views divergent thinking as one of the many indicators of creativity.

Much of the literature on creativity supports and promotes the validity of divergent thinking tests. The results of these tests have also been linked to indications of creative abilities in the context of real life. In particular, Barron and Harrington (1981) note that evidence for the validity of divergent thinking tests includes positive and statistically significant relationships found in their study between divergent thinking test scores and various creativity indicators at the elementary, junior high school, undergraduate and graduate levels. Furthermore, from very early on the validity of divergent thinking measurements has been positively related to the emergence of creative behaviour, such as creative writing and innovative work in science and business (Runco, 2010). The validity of divergent thinking tests as a means to predict general creative behaviour has been also indicated by recent research concentrating on

early childhood and adolescence. The scores observed in these tests were used to predict real-life creative behaviours in domains including art, music, sport, drama, literature and dance (Runco, 2004; Runco & Chand, 1995).

However, there are some who criticise and express concerns about the validity of divergent thinking tests (Runco, 2004). The main critics concentrate on the significance of fluence and flexibility. According to this view, divergent thinking tests appear to oversimplify these concepts in terms of creativity. Critics argue that the generation of a large amount of different ideas in these situations is based on unrealistic situations. Therefore, the tests do not and cannot properly reflect the cognitive processes actually underlying creativity. Secondly, the sole use of divergent thinking, as delineated by these tests, underestimates the importance of personality traits as well as the effect of the environment and it's impact on creativity.

In regard to the psychometric properties of divergent thinking tests Beghetto and Kaufman (2007), as well as Simonton (2000), have expressed concern about the ability of the tests to measure creativity at all levels. They distinguish three levels in particular: "little c" or everyday creative acts; "Big C" or creative acts that have a significant impact within a field; and "mini-c" or novel and personally meaningful interpretations of experiences, actions and events. Analysis of the divergent thinking tests in this context was based on a normal distribution perspective. However, literature on creativity research has since revealed a skewed distribution in populations with creativity characteristics (Batey & Furnham, 2006). Therefore, it is considered absolutely essential for any relevant research in this area to include subjects with a level of expertise in creativity. In other words any analysis necessarily has to check its interpretation against a specific sample which includes individuals who have received recognition for their creative contributions. Despite the fact that such considerations about the validity of divergent thinking tests have been expressed, the tests continue to be the most widely used measure for assessing creative thinking (Runco, 2010; Batey & Furnham, 2006).

When we turn to scholarship on theories of intelligence, the strongest conceptual connection to divergent thinking ability can be found in the Cattell–Horn–Carroll (CHC) theory. This theory is a convergence of the Cattell–Horn theory of fluid and crystallised intelligence (Horn & Noll, 1997; Horn & Hofer, 1992; Horn & Cattell, 1966) and Carroll's three-stratum theory (1993). McGrew (2009) offers a further reformation of the approach, proposing 10 different broad factors: fluid intelligence

(Gf), quantitative knowledge (Gq), crystallised intelligence (Gc), reading and writing (Grw), short-term memory (Gsm), visual processing (Gv), auditory processing (Ga), long-term storage and retrieval (Glr), processing speed (Gs), and decision speed/reaction time (Gt).

These general factors are comprised of narrow abilities (Stratum 1). In total, 70 such narrow abilities have been identified and classified (Kaufman, Kaufman & Lichtenberger, 2011). Narrow abilities "represent greater specializations of abilities, often in quite specific ways that reflect the effects of experience and learning, or the adoption of particular strategies of performance" (Carroll, 1993, p. 634). Three or more qualitatively different narrow abilities are classified under each broad cognitive ability.

There is a tendency for creativity to be linked to the CHC broad ability of fluid intelligence (Gf) in the Cattell–Horn Gf–Gc theory. Fluid intelligence (Gf) is perceived in terms of its relation to problem solving abilities, and specifically, being able to solve non regular problems. These two relationships are also highly related to creativity. However, this approach is not fully supported by new versions of the CHC theory. According to this perspective originality/creativity is classified mainly as a component of long-term storage and retrieval (Glr). According to McGrew (2009) "Some Glr narrow abilities have been prominent in creativity research (for example, production, ideational fluency, or associative fluency)" (p. 6). The Stratum 1 (narrow) abilities of Glr broad ability are presented in Table 2. In particular, the main question is what narrow abilities of long-term storage and retrieval (Glr) could be considered as overlapping with divergent thinking. It must be noted, however, that the relationship between these narrow abilities is also a matter of great importance as it establishes a stronger connection to divergent thinking.

Ideational fluency (FI), word fluency (FW) and figural fluency (FF) are all definite characteristics of creative thinking because they force the retrieval of word associations (WF) or figures (FI). Furthermore, FW is very similar to FF as both involve the retrieval of word associations, although FW also involves the ability to retrieve associations that conform to certain semantic specifications. This process results and facilitates not only the generation of novel ideas but also it restricts associations to only those that solve a particular problem. This process is equalised by abilities that consentrate more on qualitative characteristic, such as associational fluency (FA), sensitivity to problems (SP) and originality/creativity (FO).

Associative memory (MA): Ability to form associations between words that may or may not be meaningfully related to each other
Meaningful memory (MM): Ability to recall information that is related to each other in a meaningful way
Free-recall memory (M6): Ability to recall, in any order, as many items as possible from a large list of unrelated items that are presented one at a time
Ideational fluency (FI): Ability to rapidly produce a series of ideas, words, or phrases related to a specific condition or object. Quantity is emphasized, instead of quality or originality
Associational fluency (FA): Ability to produce a series of words or phrases associated in meaning to a word or concept with a limited range of meaning. Quality is emphasized, instead of sheer quantity
Expressional fluency (FE): Ability to rephrase an idea without losing its original meaning. Rephrasing is emphasized here, instead of idea generation
Naming facility (NA): Ability to produce names for concepts or things when presented with the things or a drawing of it
Word fluency (FW): Ability to produce words that have given characteristics
Figural fluency (FF): Ability to draw as many things as possible when presented with a set of visual stimulus. Quantity is emphasized here, instead of quality of originality. This is the nonverbal counterpart to ideational fluency
Figural flexibility (FX): Ability to change set and deal with a figural problem that requires a variety of approaches to find a solution
Sensitivity to problems (SP): Ability to think of a number of different solutions to problems that are practical in nature, such as naming all the uses of a particular tool
Originality/creativity (FO): Ability to produce original and unique responses to a given problem and to develop innovative methods for situations where there is no standard convergent way to solve a problem
Learning abilities (L1): Ability to learn new material generally. This is the least well-defined ability

Table 2. Narrow Abilities (Stratum 1) Subsumed by the Long-Term Storage and Retrieval (Glr) Broad Ability Factor (Stratum 2) in the Cattell–Horn–Carroll (CHC) Model of Human Cognitive Abilities. From Kaufman, J. C., Kaufman, S. B. & Lichtenberger, E. O. (2011). Finding Creative Potential on Intelligence Tests via Divergent Production. *Canadian Journal of School Psychology, 26* (2), 83–106.

Finally, it has to be clarified that fluid intelligence should not be considered as totally overlapped by divergent thinking and production. Although fluid intelligence (Gf) items may be related to creativity, these items are evaluated and approached more in regard to the usefulness or interpretation aspect of creativity than divergent production, as they mainly rely on an individual's reasoning abilities.

3.3.2 Convergent thinking as an underlying cognitive mechanism of creative production

Convergent thinking has been reported as one of the cognitive abilities underlying creative processing. However, in the early stages of creative research convergent thinking was originally perceived incorrectly as an opposite to the creativity notion. Convergent thinking refers to the cognitive process of discerning which ideas are most appropriate, or of highest quality, with the objective of arriving at a single, correct solution. In other words, the process of finding the solution to convergent thinking tasks in terms of creativity is often referred to as "thinking outside of the box". The problem solver is required to break away from obvious responses and common mental sets in order to view the problem from an unusual perspective or novel search space where the solution resides (Wiley, 1998). Brophy (2000) argues that convergent tasks are key parts of information processing models of creative problem solving and general creative processes. He also points out that:

> Scientists and other task finders and solvers create abstractions and plans, organize data hierarchies, use means ends analysis to reach goals, divide and first solve problems with the fewest unknowns, accept imperfect outcomes, and judge ideas during solution searches (Brophy, 2000, p. 440).

Convergent thinking is also closely associated with long-term memory representations. This association is considered one of the main characteristics of convergent thinking; the ability to adapt old ideas to new needs or circumstances.

3.3.2.1 Convergent and divergent thinking as complementary processes and underlying cognitive mechanisms of creative production

Although there is a significant distinction between divergent and convergent thinking, the literature supports the notion that they are complementary processes. Researchers have also recently argued that convergent thinking complements divergent thinking particularly in connection with the processing of creative production.

> Divergent thought from a single starting point generates varied ideas, whereas convergent thought starting from multiple points seeks one most true or useful conclusion (Brophy, 2000, p. 439).

More divergent thought occurs while generating definitions and solutions to problems, while more convergent thought occurs while selecting and developing these definitions and solutions. In other words, it is in situations when there is a need to change goals and

situations, for example when standard solutions or predefined goals cannot provide an appropriate solution, that we find such thinking. Under these circumstances adapation of goals and situations, as well as the removal of the barriers preventing us from reaching goals, and seeking ways to improve on existing solutions are necessary. These processes are catalysts for both divergent and convergent thought and can also be characterised as typical creative processes (Csikszentmihalyi, 1990a). The notion that the generation of creative behaviour is impossible without divergent or convergent processes is well supported by scholarship. For exaple, the most creative scientists across a variety of disciplines are top scorers on the Remote Associates Test as well as divergent thinking tests. In addition, subjects who score highly in creativity have also been shown to display a tendency to process every field and situation independently indicating a cognitive process of discerning which ideas are most appropriate, or of highest quality. They reorganise their behavioral patterns when needed, and appear to be able to alter their situations when required to think divergently or convergently (Noppe, 1996; Niaz & Saud de Nunez, 1991).

In summary, divergent thinking has been extensively investigated as a complementary creativity process (Brophy, 2000). However, much less attention has been given to convergent thinking, especially as an underlying cognitive mechanism of creative production. The traditional assessment of convergent thinking processes was done using two types of tests: the Remote Associates Test (RAT) (Mednick, 1962) and by presenting the subject with insight problems (for example, the candle problem) (Duncker, 1945). However, the RAT is by far the most applied test.

3.3.2.2 The Remote Associates Test as a measure of convergent thinking

The RAT requires subjects to find a solution that is associated with three presented words, either semantically or through the formation of a compound word. For example, for the words “birthday”, “light” and “stick”, one answer could be “candle”, as this word is associated with all three presented words. However, RAT problems usually include a triad of cue words that are not so obviously related to each other. Instead, they are related to a common associate fourth word, either through semantic association, synonymy, or by formation of a compound word. The problem is constructed in such way so that the most common associates to each cue word (the automatic/common sense word) are also not related to the other cue words. Therefore, identifying the correct associate word requires the subject to suppress the strongest associates and search for “remote associates” among the three cue words (Mednick, 1962).

The RAT was developed by Mednick (1962) and is based on his associative theory of creativity. He proposes that more creative individuals have flatter associative hierarchies that support the activation and combination of more distally related elements in the mental network (Mednick, 1962). Therefore, the more creative individuals who are better able to find a mediating link between seemingly unrelated words are expected to show superior performance on the RAT. It can also be argued that the process of generating remote associates is involved in divergent thinking as well. Higher performance with regard to divergent thinking tests also requires the suppression of common responses in order to generate more novel and unusual responses (Gilhooly, Fioratou, Anthony & Wynn, 2007).

3.3.2.3 Using the Remote Associates Test to measure convergent thinking

Several researchers have criticised the convergent nature of the RAT on theoretical grounds. They argue that the compulsory condition requiring only one allowable solution for each item makes the RAT similar to traditional analytical tests of cognitive ability (for example, IQ tests). Unlike divergent thinking tests the RAT therefore does not reflect a stable distinctive ground to the traditional approach of executive functions (Datta, 1964; Kaufman, 2009; Mendelsohn, 1976; Shapiro, 1965). It is only recently that theoretical models dealing with the associative and convergent basis of creative thinking have been examined empirically using latent variable methods, providing significant results in support of the connection between creativity and RAT. These studies provide specific experimental findings indicating that the RATs do indeed effectively measure convergent thinking abilities. More importantly, these convergent thinking abilities are actually an essential part of the underlying cognitive mechanism of creative production (Lee & Therriault, 2013; Benedek, Konen & Neubauer, 2012).

Mednick (1962) originally based the construction of the RAT on his associative theory of creativity. He sought to measure subjects' individual differences in terms of associative hierarchies. However, the RAT was soon used to assess general creativity abilities as well as creative problem solving and working memory capacities (Cushen & Wiley, 2012; Storm, Angello & Bjork, 2011). In relation to the present study it is important to note the use of the RAT in a study conducted by Storm, Angello and Bjork (2011) involving memory dynamics in creative problem solving. In their study they argue that "to think creatively, one must not only be able to think of new and appropriate ideas but one must also be able to put aside or forget old and inappropriate ideas" (Storm, Angello & Bjork, 2011, p. 1287). Therefore, they hypothesise that in

order to increase the probability of generating an appropriate creative solution to a creative problem, items causing competition must be inhibited. They conclude that this type of inhibitory process is necessary in creative problem solving. In other words the main mechanisms of the RAT are essential to creative problem solving (Storm & Angello, 2010).

Further support for the link between the RAT and convergent thinking in terms of creativity is provided by several neuropsychological studies. As the link between divergent thinking and creativity is well supported in literature, the relationship between divergent and convergent thinking can thus be used as an indirect proof of the link between convergent thinking and creativity. The process of generating remote associates has been proven to be involved in divergent thinking, as greater performance on divergent thinking tests requires the suppression of common responses in order to generate more novel and unusual responses, thus remote associations processes. However, the difference between convergent and divergent thinking is nevertheless located in the compulsory condition requiring only one allowable solution.

Electroencephalography (EEG) studies indicate that subjects undertaking a RAT demonstrate alpha power changes in the right posterior regions of the brain. Brain activity in these regions is linked to low cortisol activation, defocused attention and unconscious processing (Razumnikova, 2007; Jung-Beeman et al., 2004; Martindale & Hines, 1975). Therefore, the RAT can be seen to engage several cognitive processes that could be classified as associative (that is, linking a notion to a problem which in turn links to another notion) or insight (for example, the eureka state). There is now agreement between scholars on the mechanisms and cognitive abilities assessed by the RAT, indicating that these tests target general creative abilities and one of the main mechanisms of creative thinking, convergent thinking. However, in terms of creativity literature more acknowledgement and empirically examined research needs to be performed.

The main objections over the capacity of RATs to assess creative abilities were originally based on the idea that RATs actually do not relate to individual differences in associative abilities as originality proposed by Mednick (1962). Instead, the assessment reflects executive functions more closely related to intelligence. In other words, RATs are able to track specific executive functions more generally seen as related to intelligence than associative processing (Mendelsohn, 1976; Jacobson, Elenewski, Lordahl & Liroff, 1968; Laughlin, Doherty & Dunn, 1968; Greenberg, 1966; Taft &

Rossiter, 1966; Yahav, 1965). Taft and Rossiter (1966), in particular, question the convergent nature of the RAT. They argue that convergent thinking tests, school achievement records, as well as performance on verbal IQ, quantitative IQ, progressive matrices, speed and accuracy, and number series tasks, all correlated considerably higher with the RAT ($r = .57, .60, .46, .38, .27, .41$, and $.40$, $p < .01$, respectively). These correlations with IQ measurements were minimal when tested against tests for divergent thinking including: ideational fluency, word fluency, and total fluency, as well as flexibility, and originality scores on unusual uses and consequences tests ($r = .15, .43, .15, .15$ and $.27$, $p < .01$, respectively). These tendencies were also supported by Laughlin, Doherty and Dunn (1968).

The role of attentional processes in making remote associations is stressed by Mendelsohn (1976). He argues that attentional processes such as "the ability to receive and store in accessible form a broad range of information from the environment would serve to increase the range of elements, including unusual peripheral, or incidental elements" (Mendelsohn, 1976, p. 363) and facilitate the ability to find the single, correct mediating link (or remote association) to solve the RAT problem. This assumption offers an alternative view of the link between RAT and creativity, establishing a close relationship with attentional processes. Mendelsohn (1976) further reports that when verbal intelligence is controlled, performance in the RAT is correlated with attentional processes. His subjects were divided into two groups (the condition of each being informed or uninformed) and were asked to solve anagrams. Those who were informed were told that the anagrams fell into either an animal, food or miscellaneous category. Those in the uninformed group were simply instructed to solve the 30 anagrams. Mendelsohn proposed that individuals who scored high in the informed condition were able to do so based on the assumption that the memory search and retrieval processes involved in solving the anagrams also required the ability to simultaneously and effectively maintain the three search strategies, that is, to consider whether the answers were animals, foods or miscellaneous words.

In conclusion, although there have been some scholars who have previously questioned the psychometric properties of the RAT, particularly with regard to its ability to measure convergent thinking or creativity, the RAT has long been seen as a tool for measuring general creative ability. Furthermore, recent research on creativity indicates that the RAT is indeed a psychometric tool, targeting and reliably measuring convergent thinking as a creativity task (Benedek, Konen & Neubauer, 2012; Kaufman,

Kaufman & Lichtenberger, 2011; Arden, Chavez, Grazioplene & Jung, 2010; Nielsen, Pickett & Simonton, 2008). Therefore, convergent thinking, with the RAT as its measurement tool, is now recognised as an important aspect of the creative problem solving process (for example, it can be seen in scenarios where the subject must effectively judge and adapt ideas generated in order to achieve a novel and appropriate solution). This is in direct contrast to the idea which perceives convergent thinking as a process opposite to creativity and creative problem solving (Cropley, 2000; Brophy, 2000). In particular, current research on creative problem solving describes convergent processes as the ability to choose the most appropriate and most effective solution. This process is supported by the ability to make the necessary adjustments to the decisions or solutions that have been taken in order to reach to the most appropriate solution. This description clearly indicates that convergent thinking is an essential component of creativity (Kaufman, Kaufman & Lichtenberger, 2011; Treffinger, Isaksen & Dorval, 2002; Brophy, 1998).

3.3.3 Associative processing as an underlying cognitive mechanism of creative production

3.3.3.1 Definitions of associative processing

In creativity research literature the definition of associative processing varies according to the methodological orientation and scope of the research investigating the phenomenon (Brophy, 2001). However, there are broadly accepted definitions which provide a stable ground for the generation of some general conclusions. Associative processing therefore refers to the activation of mental networks consisting of objectively and subjectively associated concepts or mental items. The associative mental networks are determined to be structured into an associative hierarchy. In particular, there are associations or relationships that are high in the hierarchy while others are low (Sternberg, 2003). It must be noted, however, that these hierarchies refer to the associations between the items and should not be considered hierarchies of the items per se.

In relation to creativity, the traditional view with regard to associative processing is that the emergence of a creative product requires the activation of associations that are not commonly observed in the population. This is achieved when a stimulus cues a semantic representation, which in turn activates another mental item until the activations reach the appropriate/effective association (Brophy, 2001). In other words, it is believed that creative ideas occur when more uncommon elements in lower positions

in the associative hierarchy are generated or activated. A more analytical definition of associative processes in terms of creativity research indicates that creative products or ideas are generated through the recombination of existing elements. Thus we can see the importance of working memory in associative processing and consequently the role of the redintegration model, discussed above (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Benedek, Konen & Neubauer, 2012).

3.3.3.2 The effect of individual differences factors and cognitive mechanisms on associative processing leading to creative outcomes

Divergent and convergent thinking are well understood cognitive mechanisms of creativity. However, their distinctiveness has to be reported in conjunction with their shared cognitive architecture. Associative processing is considered the common element of both convergent and divergent thinking. For example, although Mednick's (1962) associative theory of creativity was used to develop the RAT for measuring convergent thinking, his ideas were mainly directed towards the establishment of relationship between associative ability and creativity. Mednick (1962) defines creative thinking "as the forming of associative elements into new combinations which either meet specified requirements or are in some way useful" (p. 221). He also suggests that "any ability or tendency which serves to bring otherwise mutually remote ideas into contiguity will facilitate a creative solution" (p. 222). Based on his associative theory of creativity, Mednick argues that observable individual differences should be related to creativity. In particular, he notes that individual differences in the organisation of associations are closely related to creativity. For example, people who score low in creativity normally have steep associative hierarchies (that is, the gradient of associative response strength for available associations to a given concept is steep, with only few associations showing high associative response strength), while highly creative people usually reveal flat associative hierarchies. In other words, creative subjects demonstrate more flexible associative links in their mental network and consequently are able to connect or disconnect associative relations more fluently than subjects described as less creative. This tendency could be one reason for developing more efficient creative problem solving abilities and behaviours.

Mednick's approach with regard to associative processing was very influential in connecting creativity and associative processing. In addition, it also provided useful and reasonable explanations for individual differences in creative behaviour. His main contribution can be seen in his definition of associative hierarchies. He explains that

non creative individuals develop strong associative hierarchies. These hierarchies are characterised as stereotypical and are dominant in problem solving, not allowing the generation of novel reactions to stimuli and problems. In other words, subjects who score low in creativity commonly reduce the generation of solutions to a specific small number of usual and stereotypical options. These options are generated because the associative constructions have an hierarchical basis. The subjects thus have pre-organised solutions located in specific strata. Only this group or hierarchical pool of options will be used to generate solutions. It is also logical to hypothesise that the capacity of this pool to facilitate novel ideas or products is minimal. On the other hand, individuals who have flatter associative hierarchies also choose solutions according to conventional associates. However, the effect of these associative hierarchies is not strong enough to allow access to, or generation of, more remote associates. However, under specific circumstances this accessibility leads to the generation of more uncommon, or rather creative, ideas and products (Mednick, 1962).

Mednick's hypothesis regarding associative processing in creative thinking is supported by Rossman and Fink (2010). The main objective of their study was to "investigate the relationship between individual differences in associative information processing and different facets of creativity" (Rossman & Fink, 2010, p. 891). One of the main measurement tools used was a modified variant of the methodology applied in Gianotti, Mohr, Pizzagalli, Lehmann & Brugger's (2001) study.

Rossman and Fink (2010) provided their subjects with pairs of words that were either semantically related or semantically unrelated. Instead of asking the participants to generate a third word that could possibly serve as a connective associative link between the presented stimuli words, as in Gianotti, Mohr, Pizzagalli, Lehmann & Brugger's (2001) study, Rossman and Fink (2010) asked the participants to judge the associative distance between the given problem words on a rating scale. Additionally, a variety of psychometric creativity tasks were implemented in the experiment. The sample, consisting of university students, was divided into groups according to certain creativity related demands in their chosen fields of study. Analysis of the results reveals a weak but significant negative correlation between originality and the rated associative distance between the unrelated word pairs. In other words, the higher level creative group estimated the distance between unrelated word pairs as being smaller than those in the lower group. Interpretation of the results supports Mednick's (1962) theory of individual differences in associative hierarchies in the context of creativity. The applied

word pair list thus can be considered as a significant method by which to measure certain dimensions of creative cognition.

Rossman and Fink (2010) conclude that the findings of their research support the hypothesis presented by Mednick (1962) and his influential theory of individual differences in associative hierarchies in the context of creative cognition. In particular, they support the idea that more creative people perceive the associative distance between the unrelated items pairs as being shorter than less creative people. In other words, more creative individuals have a more flexible associative network. The development of a creative idea or product requires the subject to temporarily inhibit conventional tendencies of information processing and build new connections between stimuli and mental representations. Rossman and Fink (2010) hypothesise that this tendency is a characteristic linked to the creative cognition.

A significant contribution of Rossman and Fink's (2010) research to this current thesis is their manipulation of the sample group, specifically division of the sample into groups according to creativity related demands in their chosen fields of study. Their findings indicate that different creativity groups vary considerably with respect to associative information processing. Students with higher creativity related demands in their fields of study demonstrated lower estimates of the distance between the unrelated word pairs when compared with students with lower creativity related demands in their fields of study. It has to be stressed, however, that there is no causation between creativity and associative information processing but rather only correlation. Similarly, individuals demonstrating higher creativity related demands reported more creativity related hobbies. Thus, they revealed higher scores on some of the extracted factors of creativity, indicating that this group actually exhibited a comparatively high level of creativity. A further interesting finding of this study is the weak tendency towards a negative correlation between psychoticism and associative information processing. This finding will be discussed below in relation to the findings reported by Eysenck (1995), as these studies reports opposite tendencies even though both support Mednick's approach.

In relation to the hypothesis of a connection between associative processes and creativity, Eysenck (1995) refers to a similar concept. He refers to the individual differences factors and the cognitive mechanisms underlying associative processing. Eysenck (1995) argues that subjects with high creative abilities have extensively flexible associative networks. Concepts such as "overinclusiveness" or "allusive

thinking" are thus considered as part of the characteristics of creative individuals. Subjects scoring high in creative abilities have the tendency to integrate an extensive number of mental items or categories when they access and process their semantic/mental network. This tendency is not observed in less creative individuals. Hence, the more creative individuals are capable of creating more relations or connective associations between single stimuli, generating an "overinclusiveness" of information. However, this tendency leads to the involvement of a large number of relations or connective associations between the processed items and the problematic situation. This characteristic, in turn, causes some kind of breakdown of filter mechanisms, which are then responsible for excluding irrelevant mental items in order to facilitate efficient information processing. Subjects diagnosed as psychotic tend to reveal such behavior.

Martindale (1995) introduces a similar idea to Eysenck in his approach to creativity. According to this idea creative people are able to produce creative associations during their primary processing by defocused attention and free associative thinking. However, Martindale (1995) extends this approach by implementing a second stage of processing, which is characterised by logical and analytic thinking. During this stage, creative individuals evaluate and structure their ideas, which are characteristics of convergent thinking. The oscillation between primary and secondary processes is an essential characteristic of creative thinking and production. This theoretical approach also reveals the importance of the convergent and divergent thinking combination.

It must be noted that information processing in terms of creative problem solving processes is crucial in explaining individual differences in performance. Mumford, Mobley, Reiter-Palmon, Uhlman and Doares (1991) as well as Treffinger, Isaksen and Dorval (2000), while revewing creative problem solving processes, all conclude that these processes can be distinguished between divergent and convergent thinking processes. However, they point out that associative processes are actually engaged within the whole process. Finally, although it is not common, but rather only observed in creative individuals, there is a shift between divergent and convergent thinking processes.

Knowledge is highly significant in relation to this perspective. Turner, Henry and Smith (2000) indicate that, according to the current view of human cognition, information is stored and interpreted in categorical structures (Sternberg, 2003). These categorical structures, also known as schemata, construct an organised and interrelated

network of mental representations. Central features of each category affect the extent of interrelations. Furthermore, these categories can have a procedural or declarative status. Declarative categories refer to the objects and object properties in some domain, while procedural categories refer to principles for applying or acquiring declarative information. In relation to the associative processes Mumford, Mobley, Reiter-Palmon, Uhlman and Doares (1991, p. 101) comment that "it is further assumed that these procedural and declarative categories are created from past experience and are systematically related to each other in associative networks".

In most problem solving attempts, individuals try to recall, and eventually choose, implemented solutions that were available in the past (Csikszentmihalyi, 1990b). Further, as Freyhoff, Gruber and Ziegler (1992) suggest, individuals often choose the initial available solution identified. In contrast, creativity requires the production of novel solutions to problems. Choosing the first available solution therefore does not contribute effectively to creativity. Instead, creative thinking involves the generation of innovative, alternative solutions or divergent thinking. Creativity, however, is not only a matter of divergent thinking because selected alternative solutions need to be evaluated with respect to their potential effectiveness. This evaluation component implies a need for convergent thinking. Here we can see how both convergent and divergent thinking must be applied in an integrative way so that evaluation does not preclude the generation and application of potentially viable alternatives (Isaksen & Parnes, 1985). The need for both divergent and convergent thinking, as well as the ability to switch between the two processes, is thus an essential characteristic of creative problem solving which underpins the importance of associative processing.

3.3.3.3 The role of associative processing in creative thinking

Associative processes are related to the main underlying cognitive mechanisms of divergent and convergent thinking. As creativity requires the production of novel solutions to problems as well as the evaluation of such solutions with respect to their potential effectiveness, the implementation of divergent and convergent thought processes is necessarily a de facto requirement of the creative product. Divergent and convergent thinking are well understood cognitive mechanisms of creativity, while associative processing is also considered a common element of convergent and divergent thinking. In relation to creativity, associative processing requires that the emergence of a creative product involves the activation of associations that are not commonly observed in the whole population. For example, the activation and retrieval

of remote associations is likely to support divergent processes where the goal is to generate many unusual solutions (for example, “Think of as many uses for a brick as possible”). On the other hand, the ability to initiate a wider associative spread and access remote concepts is also likely to promote success on a convergent creative thinking task such as the RAT where the goal is to identify a solution that is distally related from the original stimulus. In summary, the shared cognitive architecture of convergent and divergent thinking can be tracked at associative processing, which is thus considered as a common element in both types of thinking.

There have been several attempts made to describe divergent and convergent thinking by linking them to the associative processes. For example, research has revealed that implicit spreading of activation causes the emergence of insight or at least foundations for such a solution (Bowers & Jung-Beeman, 2003; Bowers, Farvolden & Mermigis, 1995). As previously indicated, creative processes can be affected by incremental steps based on existing knowledge (Turner, Henry & Smith, 2000). In relation to associative processes, Mumford, Mobley, Reiter-Palmon, Uhlman and Doares (1991, p. 101) state “it is further assumed that these procedural and declarative categories are created from past experience and are systematically related to each other in associative networks”. Creativity is also closely related to unconscious activity that can be stoped by engagement in explicit tasks such as verbalisation during the problem solving process (Dominowski, 1995). Finally, attentional processes as well as associational and ideational fluency (Mendelsohn, 1976) all affect creativity. However, all of these findings can only provide an indirect foundation for establishing the importance of associative processes in creativity.

Benedek, Konen and Neubauer (2012) investigated the validity of associative abilities with respect to divergent thinking, and also, on a more general level, with respect to creativity and intelligence. They suggest that:

> Research on creativity and cognitive abilities tends to focus either on low-level creativity-related associative processes or on high-level creativity-related abilities. Therefore, the main aim of the present study is to link these two approaches in order to examine whether associative abilities can be conceived as relevant elementary cognitive processes involved in the more complex cognitive process of creative ideation (Benedek, Konen & Neubauer, 2012, p. 274).

They use as a starting point the influential theory of Mednick (1962) about the relationship between associative ability and creativity which defined creative thinking

"as the forming of associative elements into new combinations which either meet specified requirements or are in some way useful" (Mednick, 1962, p. 221). Furthermore, they reiterate what Mednick (1962) concluded, that is: "any ability or tendency which serves to bring otherwise mutually remote ideas into contiguity will facilitate a creative solution" (Mednick, 1962, p. 222). Thus they define associative processing as the ability to fluently retrieve and combine remote associations, with respect to divergent thinking and intelligence. Their hypothesis is based on the combination of two tendencies in current literature. Empirical approaches to cognitive ability indicate that divergent thinking represents an effective predictor for the emergence of creative thinking. In addition, associative abilities, the process of retrieving and combining remote associations also facilitates creative production. Combining these two approaches Benedek, Konen and Neubauer (2012) claim that a significant relationship between associative processes and divergent thinking can be observed.

In their experiment, they use four word association tasks in order to measure the different aspects of associative ability considered relevant for creative idea generation. These aspects include: associative fluency, flexibility of association, semantic dissociation, and associative combination.

(a) The associative fluency test was based on a standard task for assessing typical unrestricted association behaviour. The subjects had to generate as many associations as possible in relation to the provided word.

(b) Flexibility of association was evaluated using an association chain task. In this task the participants had to provide an association (related word) for the presented word, while all following associations/words had to be related to the respectively last associative response (for example, summer: "beach, sand, castle, knight, horse, race..."). The hypothesis is that the task measures the spontaneous associational flexibility by estimating the total number of associative concepts.

(c) The third association task tested dissociative ability. The participants had to respond to the provided stimulus with a semantically unrelated word. Furthermore, they had to provide additional words that were unrelated not only to the initial stimulus but also to the words they generated (for example, summer: "computer, banana, bicycle..."). Benedek, Konen and Neubauer (2012) comment that "This task can be assumed to assess a much more deliberate variant of associative flexibility as compared to the association chain task". However, they

did not take into consideration individual differences with regard to the personal constructs of association.

(d) Finally, the associative combination task was conceived as very similar to the RAT, discussed above (Mednick, 1962). Participants were provided with two semantically unrelated words. The task required them to generate associations (words) that were connected to both stimulus words at the same time (for example, summer–high: "airplane, temperature, expenses..."). The associative combination task targeted the processes of conceptual combination, bisociation and associative combination.

Further to the association tasks the study included creativity measurements such as a divergent thinking task, a self reported creative ideational behaviour measurement and a self reported creativity assessment. The methodology included assessment of the general cognitive and psychomotor ability of participants in respect to intelligence, word fluency, speed of information processing and writing speed. Finally, the structure of personality was assessed by the NEO-Five Factor Inventory (NEO-FFI; Borkenau & Ostendorf, 1993).

The importance of Benedek, Konen and Neubauer's (2012) study is located mainly in the adapted methodology. Their inclusion of four association tasks making it the first study to experimentally investigated associative ability by targeting significant aspects of associative ability in relation to creativity. Analysis of the data revealed that there was a significant positive correlation between the four association tasks: associative fluency, associative flexibility, dissociative ability and associative combination and the measures of creativity (r =.55 to.62, p <.01). Also, regression analysis indicated that the four association measures explained almost half ($R2$ =.47) of the variance in divergent thinking ability; the dissociative ability (β =.28, p <.001) and the associative combination (β =.26, p <.05). Further analysis using Structural Equation Modeling demonstrated that the dissociative ability and the associative combination predicted creativity (for dissociative ability γ =.28, p <.001 and for associative combination γ =.30, p <.05). Furthermore, they could not predict intelligence, making apparent the importance, as well as the relationship, of divergent thinking and its main underlying cognitive and associative processes with creativity and not intelligence.

Finally, Benedek, Konen and Neubauer (2012) state that:

> Summing up, we conclude that specific associative abilities qualify as valid elementary cognitive abilities underlying creativity. They allow for an efficient and reliable

> assessment and thus might be considered useful as basic indicators of creative potential (p. 280).

Their results support the hypothesis that creativity is related to executive processes (for example, inhibition), while their approaches may eventually help us to understand "creativity as an extraordinary result of ordinary [cognitive] processes" (Sternberg & Lubart, 1996, p. 681). In particular, the abilities of dissociation and associative combination represent relevant elementary cognitive abilities involved in creative thinking. Dissociative ability represents the capacity to dissociate from salient concepts and is also related to divergent thinking. Thus, dissociative ability allows access to mutually remote concepts and facilitates the individual's move away from concentrating on the initial, obvious solution to the problem. This is in line with recent evidence on the significance of switching idea categories in divergent thinking (Nusbaum & Silvia, 2011). The study also demonstrates that associative combinations not only allow individuals to access mutually remote associative elements but more importantly help the individual to combine these remote concepts in useful ways.

The findings also complement the evidence of other studies employing unrelated word pairs. Vartanian, Martindale and Matthews (2009) argue that creative people are faster in judging the relatedness of concepts. They propose that a higher speed in terms of relatedness judgments might be advantageous for the fast identification of potentially useful conceptual relationships. This conforms to a highly functioning retrieval ability which not only involves convergent processing (that is, scanning for related associative elements) but also divergent processing (that is, scanning for unrelated associative elements). In highly creative people, this is complemented by the ability to generate adequate associative relations with supposedly unrelated concepts.

The construct of associative fluency, perceived as based on a semantic category notion, is specified as a predictor of divergent and convergent thinking. In other words, associative fluency is considered as a major creative thinking process especially when it is linked and investigated in problem solving activity. Literature on problem solving reveals that individuals commonly engage in an initial analysis before actually performing the problem solving activity. This task analysis involves searches of long-term memory, by means of episodic and semantic knowledge, for relevant information or ideas that can be applied to the task.

Gilhooly, Fioratou, Anthony and Wynn (2007) sought to explore the cognitive processes underlying such divergent thinking using two experiments. They noted the

presence of four main strategies—memory, property, broad use and disassembly—used in the production of novel solutions. Initial solutions are derived from a memory strategy that involves retrieval from long-term memory of previously used or learned solutions. This is an automatic process and consists of retrieving solutions associated in terms of past experience with the target objects. This strategy of long-term memory also contributes to the average novelty of production as it allows adjustments. Individuals tend to generate unusual solutions automatically from their memory. The general pattern of episodic, contextualised retrieval strategies followed by more semantically based strategies indicates that associative processes are engaged in the creative production process. Thus unmediated associative processes are activated parallel to the preliminary task analysis processes. For example,

> a wooden chair (probably initially categorized only as a member of the category 'things which one can sit on') could be cross-classified as a member of many other categories such as 'things that could be used as emergency firewood' (Gilhooly, Fioratou, Anthony & Wynn, 2007, p. 623).

The second experiment revealed that individuals characterised by less executive/creative capacity experience difficulties in divergent production, switching to other strategies and resisting the intrusion of previous uses. In contrast, individuals with greater executive capacity were able to produce more "new" responses in divergent production. Overall, results from this study demonstrate that a memory search in which unmediated ideas are fluently retrieved is a precursor to more complex cognitive processes involved in generating and developing novel ideas.

Kaufman, DeYoung, Gray, Brown and Mackintosh (2009) hypothesise that associative learning ability can predict variance in general intelligence above and beyond the variance predicted by working memory capacity and processing speed. They define associative learning as "the ability to remember and voluntarily recall specific associations between stimuli" (p. 374). It must be noted that associative learning in this study was approached in terms of a different level of complexity in comparison to Benedek, Konen and Neubauer's (2012) study. In other words, associative learning was perceived as an executive process incorporating more than the four associative processes explored in Benedek, Konen and Neubauer's work. In relation to the associative learning tasks employed in Kaufman, DeYoung, Gray, Brown and Mackintosh's (2009) study, individuals were shown to consciously and voluntarily remember associations. Thus the authors conclude that different mechanisms are likely

to be involved in explicit versus implicit associative learning. This allows us to assume, albeit indirectly, that associative processing and creativity are partially dictated by explicit strategies. As a result, associative processing and working memory can be said to both be predictors of general intelligence. However, it should be pointed out that the sample size of this study was relatively low raising questions about the gravity of the findings. In addition, the authors started their study by noting that "only one working memory task is the use of multiple associative learning tasks, creating a model that is slightly unbalanced in the number of markers for each of our three predictors, with the most markers for associative learning" (Kaufman, DeYoung, Gray, Brown & Mackintosh, 2009, p. 380).

In conclusion, the discussion above has demonstrated that associative processing and working memory should be considered as distinctive cognitive processes. They are separate elementary cognitive mechanisms although they both support general intelligence and creativity. Evidence exists that working memory and associative processing rely on different regions of the prefrontal cortex (Petrides, 2000; Petrides, Alivisatos, Evans & Meyer, 1993). Nevertheless, in any discussion of intelligence and creativity they should always be taken into consideration, as previous scholarship indicates that they both have an affect on creative behaviour the first as a supportive mechanism and the second as a pillar of creative cognition. The literature summarised so far also suggests that individual differences in the flexibility of the associative network could be seen as an important correlate of creativity.

4. Creativity and working memory

Linguistic and psycholinguistic researchers have recently sought to focus more attention on individual differences in terms of creativity, particularly on the basis of specific associative, divergent and convergent thinking processes in language processing (DeYoung, Flanders and Peterson, 2008; Gilhooly, Fioratou, Anthony & Wynn, 2007; Nusbaum and Silvia, 2011). This has opened new lines of research into examining how higher order cognitive mechanisms may uniquely contribute to creative thinking, working memory and language processing (Unsworth, Redick, Heitz, Broadway & Engle, 2009; Conway, Cowan, Bunting, Therriault & Minkoff, 2002). Some studies have also indirectly investigated the relationship between working memory and creativity. The majority of these studies have offered the hypothesis that working memory capacity is a prerequisite for creativity, and specifically in relation to cognitive flexibility, abstract thinking, strategic planning, and processing speed in long-term memory (Deitrich, 2004). In simple terms, working memory capacity can be seen to benefit creativity by enabling the individual to maintain attention to the task as well as preventing undesirable mind wandering (De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012).

There is no research to date which specifically investigates how creativity and creative strategies can affect the strategies incorporated in working memory processes. However, some assumptions can be indirectly draw from relevant contemporary research. For example, selective attention, which involves the ability to focus cognitive resources on information relevant to goals, has been shown to influence working memory performance (Gazzaley & Nobre, 2012), while both modality dependent working memory mechanisms and modality independent attention control mechanisms do have an impact on insight problem solving (Chein & Weisberg, 2013). Furthermore, Lee and Therriault (2013) link working memory prerformance with the underlying cognitive mechanisms of divergent, convergent thinking as well as associative processing, albeit indirectly. Further indirect support for the association between working memory and creativity comes from neuropsychological studies as well medical studies, like those which have demonstrated that Ritalin (methylphenidate) administration significantly decreased symptoms of attention deficit hyperactive disorder (Swartwood, Swartwood & Farrell, 2003) while improving working memory and creativity.

Takeuchi et al. (2011) offer a different approach on the question of creativity and working memory. Although they report that creativity and working memory capacity appear to have a positive correlation with intelligence they also suggest that creativity and working memory capacity (not working memory) have opposing characteristics, possibly in terms of diffuse attention. Their work was based on research findings revealing that individuals scoring highly on creative tasks nevertheless remained inefficient in terms of performing appropriately when asked to complete a selective attention task (Necka, 1999) and appeared unable to avoid information irrelevant to the problematic situation. In contrast, other scholars argue that the positive correlation between creativity and working memory can be observed in individuals with high or normal intelligence (Sternberg, 2005; Baddeley, 2003).

Other research has highlighted the fact that individuals with low working memory capacity demonstrate difficulty in blocking out, or inhibiting, distracting information (Conway, Cowan, Bunting, Therriault & Minkoff, 2002) and can perform poorly on selective attention tasks (Engle, Tuholski, Laughlin & Conway, 1999). Furthermore, hyperactive children, characterised by an impairment in ability to focus their attention, are often assessed as creative and yet they reveal working memory impairments (Kuntsi, Oosterlaan & Stevenson, 2001). Finally, the association between creativity and working memory capacity is now known to be at least partly mediated by genetics. The prevalent genotype of the neuregulin 1 gene that increases the risk of psychosis (Kéri, Kiss & Kelemen, 2009) is associated with lower working memory capacity (Stefanis et al., 2007) and increased creativity (Kéri, 2009).

In summary, the literature to date reports findings indicating that there is a positive relationship between working memory and creativity. However, the main disadvantage of these studies is that the majority of them have not employed working memory tasks requiring creative abilities or solutions (Yeh, Lai, Lin, Lin & Sun, 2015). This methodological weakness needs to be addressed, especially with respect to the already revealed experimental findings indicating that working memory and creative thinking share higher order processes (Lee & Therriault, 2013). Complex cognitive processes including: the retrieval and processing of information, identification of useful strategies, supervision of mental processes, handling of complex conceptual relationships, and evaluation of ideas, are all cited in both working memory and creativity literature (Runco, 2004; Sub, Oberauer, Wittmann, Wilhelm & Schulze, 2002; Runco & Chand, 1995; Baddeley, 1992).

Lin and Lien (2013) outline specific methodological questions regarding the assessment of creativity that need to be answered. In particular, research into the relationship between creative abilities and underpined cognitive variables, incorporating divergent thinking tasks, or insight problem solving tasks is important if we are to seek to understand and to measure creativity. Inconsistent findings have been reported because of a tendency to ignore various important factors. As Kaufman, Kaufman and Lichtenberger (2011) note, because of this tendency, associative processes have often been left without psychometric screening. A typical example is the inconsistent findings of two studies regarding the relationship between creativity and emotion (Isen, Daubman & Nowicki, 1987; Whereas, Adaman & Blaney, 1995).

When creativity was assessed using insight problem solving measurements, the emotional state of the participants was positively correlated with creativity (Isen, Daubman & Nowicki, 1987). Whereas, Adaman and Blaney (1995), using divergent thinking tasks as a measurement of creativity, report that positive as well as negative emotional states both facilitated creative performance. The same inconsistencies were observed also in studies investigating the relationship between creativity and intelligence. In particular, studies supporting the approach of "the threshold theory" indicate that a certain level of intelligence is required for creativity. However, there is no investigation of the correlation between intelligence and creativity beyond that point. Creativity levels were mainly assessed using divergent thinking tests. When creativity has been assessed using additional measurements researchers have found that intelligence exhibits a stable positive correlation with creativity (Sternberg, 2003; Sternberg & Lubart, 1996), indicating that more work needs to be done in this area.

4.1 Significant studies on the relationship between creativity and working memory

As mentioned above, to date only a few studies have investigated the relationship between working memory and creativity, and then only indirectly. This is usually in the sense of assuming that working memory benefits creativity for it enables the individual to maintain attention to the task and prevents undesirable mind wandering (De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012). However, the relationship between creativity and working memory has been hypothesised on the basis of findings in other studies, indicating that working memory predicts intelligence and intelligence is indeed a significant predictor of creative thinking.

Executive processes related to intelligence, such as cognitive flexibility, abstract thinking, strategic planning, and processing speed in long-term memory also make major contributions to creative thought (Deitrich, 2004). In addition, higher order cognition, including the monitoring and regulation of cognitive processes, employment of strategies, searching for information, judging, and decision making during complex tasks are all closely related to intelligence and creativity (Engle, Tuholski & Laughlin, 1999).

In terms of working memory itself, as an executive ability it has been hypothesised and proven to correlate with fluid intelligence (Unsworth, Redick, Heitz, Broadway & Engle, 2009; Conway, Cowan, Bunting, Therriault & Minkoff, 2002; Conway, Kane & Engle, 2002; Engle, Tuholski & Laughlin, 1999). Furthermore, working memory is a multicomponent system, consisting of: storage components, phonological loop, visuo-spatial sketchpad and executive attention control components, as well as the central executive and episodic buffer. As such a multicomponent system it could easily be linked to the higher order cognitive functions and consequently creativity (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012). The episodic buffer, in particular, is assumed to hold integrated episodes or chunks in a multidimensional code and to operate as a buffer store not only between the different components of working memory, but also as a connection between working memory components and long-term memory operations and representations. This latter assumption establishes a direct relationship with the cognitive underpinnings of creative thought. Working memory capacity largely controls the stimultaneous storing and processing of information during activities such as the acquisition of new knowledge and language, reading comprehension and problem solving (Baddeley & Wilson, 2002). It is also believed to influence how successful people are at overcoming distractions and appropriately shifting attention during complex tasks and processing language (Unsworth, Redick, Heitz, Broadway & Engle, 2009; Conway, Cowan, Bunting, Therriault & Minkoff, 2002).

Studies concentrating on intelligence have noted that working memory capacity has a positive correlation with divergent thinking (Sub, Oberauer, Wittman, Wilhelm & Schulze, 2002) as well as performance on tasks requiring insight problem solving (DeYoung, Flanders & Peterson, 2008). Sub, Oberauer, Wittman, Wilhelm & Schulze (2002), using structural equation modeling technique, demonstrate that working memory is indirectly related to creativity. A battery of 17 intelligence and working

memory tasks, chosen to represent the proposed facet structure of working memory were administrated to 113 individuals. With regard to creativity measurements, there were three distinct activities:

1. Masselon: Participants had to write down as many different sentences as possible using three given words.
2. Drawing objects: Participants had to draw as many different objects as possible using four given geometrical elements.
3. Telephone numbers: Participants had to write down as many different six-digit telephone numbers. The numbers had to follow different principles that could help in remembering them (N).

For all of the above creativity tasks, scoring was based on the number of different categories of ideas produced, or on the number of ideas produced. The results revealed, using structural equation models, that working memory is closely connected to intelligence. However, the models also indicated that intelligence is comprised of speed memory, creativity and reasoning latent variables. In particular, the storage, processing, and coordination working memory latent variable and the supervision working memory latent variable predicted the creativity factor (β = .39 and β = .21, respectively).

DeYoung, Flanders and Peterson (2008) investigate individual differences in cognitive abilities and how they contribute to solving insight problems. The authors suggest that three types of cognitive abilities contributed independently to insight: convergent thinking, divergent thinking and breaking frame. Convergent thinking was further broken down into verbal intelligence and working memory, which might be particularly relevant to solving linguistically presented insight problems. These two constructs also predicted insight independently of each other and of divergent thinking and ability to break frame. Finally, divergent thinking and ability to break frame were uniquely associated with insight problem solving but not noninsight problem solving, thus demonstrating discriminant validity. Working memory was assessed with a self-ordered test used in neuropsychological studies. Overall, the authors argue that working memory abilities demonstrate a positive correlation with performance on tasks requiring insight problem solving and, specifically, creativity. Furthermore, within each of the three types of ability, in this study it was possible to examine more specifically differentiated cognitive abilities by breaking down intelligence into working memory (a component of fluid intelligence) and verbal intelligence. Such finer differentiations may be of particular interest in the domain of divergent thinking. This study found that, of

three different indices of divergent thinking (fluency, originality, and flexibility), only flexibility was independently predictive of insight. Fluency was significantly correlated with insight, but only because of variance it shared with flexibility. This suggests that flexibility, the ability to switch repeatedly between categories or perspectives, may be particularly important in divergent thinking. These results make apparent the need for fine methodological variations as the present thesis incorporotaed.

Regarding the abilities of individuals to employ creative strategies Nusbaum and Silvia (2011) propose that creative people are more successful at overcoming interference caused by automatic, unoriginal responses, and therefore, are more successful at using strategies to generate novel responses on divergent thinking tasks. Their study, comprised of two latent variable studies, explores the role of executive and strategic processes in the fluid intelligence and creativity relationship. Creativity was assessed by two divergent thinking tasks (for example, “unusual, creative, and uncommon” uses for a brick and a knife). They showed that fluid intelligence predicted the ability to learn and apply a complex strategy only in a divergent thinking test (Nusbaum & Silvia, 2011). Their main assumption was that intelligence is more central to creative cognition than is currently believed by creativity research. However, they did not tested their hypotheses in other more valid approaches to creative thinking apart from the traditional divergent thinking conception. But they considered sufficient the relativelly old and not supported by recent research distiction between divergent and convergent thinking. Furthermore, they based their assumption on the characteristics of the general fluid intelligence without investigate the concrete components of fluid intelligence. In other words they did not investigated working memory, as general conception or its components per se. This issue was partially resolved by incorporating clustering and switching tasks (these tasks require by defolt working memory competence) (Gilhooly, Fioratou, Anthony & Wynn, 2007). The authors conclude that higher order cognitive abilities play important roles in creative thought, and should be evaluated for their unique and interactive contributions to individual differences in creative ability. In other words, the active maintenance of any strategy, especially a creative strategy, depends on working memory. However, this study does not clarify what actually determines the choice of appropriate strategy and whether any strategy can be employed during working memory executive functioning. The present thesis aims to fill this gap in our understanding.

Further support for the benefits of approaching creativity as an executive process is provided by Gilhooly, Fioratou, Anthony and Wynn (2007). This study is especially significant to the present study as it indicates that the employed strategies in working memory procedure have measurable and significant impact on performance. In particular, Gilhooly, Fioratou, Anthony and Wynn (2007) propose that divergent thinking, one of the cognitive foundations of creativity, incorporates strategy selection, category fluency, mental disassembling of figures, alternating between ideation and evaluation, and breaking set in the face of interference strategy selection.

Gilhooly, Fioratou, Anthony and Wynn's (2007) research consisted of two experiments. The first experiment revealed that one of the crucial incorporated strategies in creativity is retrieval of pre-applied solutions from long-term memory. This is a relatively automatic process and the uses retrieved are those associated with past solutions to the referent problem. This memory strategy was further associated strongly with fluency of use production and made an independent contribution to average novelty of production. Thus, we can see how extensive use of the memory strategy can generate unusual uses. The authors comment that the initial response to a problematic situation tends to be based on contextualised personal experience stored as episodic or more generalised autobiographical memories. Thus, the retrieval from long-term memory is assumed to be automatic and fast. It does not require extensive executive capacity but the active engagement of working memory is essential. However, a second level of processing or more general later response does appear to require more time and effort as well as executively loading strategies. Thus, the second level requires more active active engagement of working memory

The second experiment investigated the effect of executive capacity in producing both new and old solutions. Ability to produce "old" solutions, presumed to be derived from memory of pre-known uses, was associated with ability to retrieve items from a well-known taxonomic category. Item retrieval is by definiton linked to working memory. The authors argue that memory strategies underlie performance and involve low executive loads. Participants characterised by less executive capacity as this is dictated by working memory therefore find it harder in divergent production to switch to other strategies and to resist intrusion of previous uses.

The confirmed hypothesis of Gilhooly, Fioratou, Anthony and Wynn (2007) regarding category fluency is significant in terms of the results of the present thesis. They report that letter fluency (an executively loading task) is related to production of

"new" uses while category fluency is related to production of "old" uses. Thus, divergent thinkers exhibit higher rates of inhibiting common responses and deliberate switching of retrieval cues. These are processes believed to engage to central executive component in working memory (Lee & Therriault, 2013). In other words, the high executive ability (working memory strategy) has a significant effect on the recall of stable representations, but this does not work the other way. Stable (old) representations do not affect the executive capacity although the ability to produce new taxonomic associations has a positive effect on executive functioning. Finally, the general pattern of episodic, contextualised retrieval strategies followed by more semantically based strategies was also found by Vallee-Tourangeau, Anthony and Austin (1998) as well as Walker and Kintsch (1985), in studies of ad hoc and taxonomic category generation, respectively.

Takeuchi et al. (2011) reviewed previous studies from different fields and argue that creativity and working memory capacity (not working memory itself) have opposing characteristics, possibly in terms of diffuse attention. The aim of their study was to investigate how creativity relates to brain activity during working memory tasks. They used functional magnetic resonance imaging (fMRI) in n-back working memory paradigm. This use of n-back paradigm could be considered as one of the main disadvantages of the study as this task does not require the incorporation of creativity abilities. Therefore, there was no need in the tasks for employment of creative abilities and consequently no emergence of creative strategies. Creativity was therefore assessed by using a divergent thinking test. Analysis of the data revealed that creativity and working memory performances did not correlate. However, multiple regression analysis indicated that there was no significant correlation between creativity and brain activities during the 0-back task. The authors state that after controlling for sex, age, accuracy and reaction time on the 2-back task, the score of Raven's Advanced Progressive Matrix and the score of the digit span, a multiple regression analysis revealed that creativity scores were significantly and positively correlated with brain activity during the 2-back task in the precuneus (x, y, x = 9, −57, 27, t = 3.88, p = 0.030 corrected for multiple comparisons at the cluster size with an underlying voxel level of $P < 0.005$).

Takeuchi et al. (2011) further propose that reduced deactivation in the precuneus during a working memory task is associated with creativity. The authors explain their findings by suggesting that creative individuals reveal reduced task induced deactivation in the precuneus during working memory task performance due to their

impaired ability to suppress irrelevant cognitive activity during a complex cognitive task. The precuneus is one of the regions that is deactivated during cognitive tasks. They also note that in creative individuals the failure to suppress "default mode network" (the deactivated areas of precuneus) activity is beneficial for the production of creative ideas. This is achieved because this failure allows the association of different ideas represented in different networks. The authors also claim that creative production is mediated by this failure of "default mode network" suppression as it allows the elaboration of brain networks with different structures to organise a different network. In other words it allows for the dynamic exchange of cognitive strategies. This claim is supported by Heilman, Nadeau and Beversdorf (2003), suggesting that the frontal lobes are important in creativity and more specifically in divergent thinking.

The frontal lobes have significant connections with the polymodal and supramodal regions of the temporal and parietal lobes where mental representations and knowledge are stored. These connections might selectively inhibit and activate portions of posterior neocortex, which in turn are responsible for the development of creative ideas. Heilman, Nadeau and Beversdorf (2003) offer specific recommendations regarding the gravity of knowledge and divergent thinking as isolated quantities. They argue that knowledge and divergent thinking alone are insufficient to allow a person to produce creative ideas. The binding of different forms of knowledge, stored in separate cortical modules that have not been previously associated is absolutely essential. Creativity requires co-activation and communication between regions of the brain that ordinarily are not strongly connected. The studies of Takeuchi et al. (2011) and Heilman, Nadeau and Beversdorf (2003) are especially significant for the present thesis as they partially provide a neuropsychological basis for the assumption of a switch between strategies during working memory tasks. Although the aforementioned argument is not directly addressed in their studies (that is, neither study employed creativity specific working memory tasks), it is nevertheless a significant indication for such speculation.

Dietrich (2014), in a review article, outlines the framework of creativity based on functional neuroanatomy. She perceives working memory as a prerequisite for cognitive flexibility, abstract thinking, strategic planning, and processing speed in long-term memory. The main assumption linking creative processing of information with normative information processing is that every neural circuit develops innovative combinations of information as it carries out any information processing. Also, the more

integrative the neural structure involved in the computations, the more combinational novelty might occur. However, the crucial characteristic of creativity, that of appropriateness, depends on the higher order structures of the individual. Dietrich (2014) describes how creativity and working memory are linked with regard to neuroanatomy.

The prefrontal cortex is linked to creative process and working memory on the basis of three functions. Firstly it evaluates the appropriateness of a novel thought. As working memory buffer reflects a conscious process, a novel idea becomes an insight only when it is represented in working memory. However, novel combinations of information are constantly generated, regardless of the state of attentional control of working memory. Therefore, during the second stage after insight is accomplished, the higher cognitive functions, such as central executive and episodic buffer, are implemented. This allows for directing and sustaining attention, retrieving mental representations, thinking abstractly, and considering impact and appropriateness. During the final stage, problem solving techniques are applied. Planning and executing relevant aims while at the same time sustaining the main goal in an activated state are functions located at the prefrontal cortex.

The study of Dietrich (2014) also clarifies working memory limitations with regard to loading capacity and chunking. When complex information has to be processed by working memory then a threshold overload may be caused. This in turn invokes executive processes. The available solution is to collapse dimensions into fewer chunks and/or process those chunks. However, this assumption has not ever tested and the confirmation of such an hypothesis requires the implementation of working memory tasks relevant to creativity (Baddeley, Hitch & Allen, 2009).

De Dreu, Nijstad, Baas, Wolsink and Roskes (2012), based on findings indicating that executive control has a positive effect on creativity, hypothesise that: “working memory capacity relates to creative performance because it enables persistent, focused, and systematic combining of elements and possibilities (persistence)” (p. 656). They tested their hypothesis by performing four experiments. The first experiment showed a negative correlation between working memory load and creativity. The second indicated positive associations between time-on-task and creativity among individuals high, but not low, in working memory capacity. The third demonstrated that high working memory capacity led to high creative performance. And the fourth revealed that working memory predicted ideation due to the persistent (rather than flexible)

processing. The combined the results of the four experiments led the authors to make three general conclusions:

> (a) working memory not only predicts fluency but also the hallmark of creativity: insight performance and original ideation (Studies 1–4), (b) working memory relates to creative insight and ideation over and beyond general intelligence (Study 2), and (c) working memory relates to creativity because it enables persistence (that is, sustained task-directed effort) rather than cognitive flexibility (Studies 2–4) (De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012, p. 664).

The results of De Dreu, Nijstad, Baas, Wolsink and Roskes (2012) were used in order to explain some of the findings in the study of Yeh, Lai, Lin, Lin and Sun (2015). The hypothesis of this study was based on the idea that the creative processes largely comprise the retrieval, integration, and retention of knowledge as well as close connections between cues and the activation of knowledge (Yeh, 2011). Thus, when working memory has more available resources and greater efficiency, creative solutions should be enhanced. It has to be pointed out that the main objective of the study was to investigate the effect of stress stimuli influence stress hormone and subsequently working memory and creativity. However, the findings do allow for the establishment of an indirect correlation between working memory and creativity. In particular, the results indicate that working memory has a significant positive effect on creative performance.

As De Dreu, Nijstad, Baas, Wolsink and Roskes (2012) show, working memory operates two critical functions; maintaining novel information in an activated state and discriminating between task-relevant and task-irrelevant information. On the basis of these assumptions the authors interpret their results. They note that working memory capacity is positively related to creativity and working memory capacity predicts original ideas because it allows for persistent (rather than flexible) processing. The ability to maintain attention is an additional explanation. Effective and creative problem solving is achieved as working memory controls attention, resists distraction, and narrows the search through a problem space (Wiley & Jarosz, 2012). Accordingly, working memory may influence creativity via attention on task-related information and persistence. Finally, the authors emphasise the role of executive control within working memory procedure as a factor that affects creativity.

Benedek, Konen and Neubauer's (2012) study also suggests a relationship between creativity and working memory. Using latent variable models, they assessed

three specific executive abilities that are strongly related to working memory — updating, shifting and inhibition — examining their common and differential relations to fluid intelligence and creativity. The analysis reveals that both updating and inhibition significantly predict divergent thinking and overall creative task performance. Their findings with regard to inhibition are also supported by other studies indicating that it is able to facilitate creative thinking by suppressing interference caused by dominant response tendencies. According to the concept of creativity based on the activation and retrieval of ideas that are only remotely associated with the problem or stimulus, they point out the importance of inhibition. Effective working memory abilities are supported by effective inhibition of salient, strongly related concepts (Gupta, Jang, Mednick & Huber, 2012; Gupta, 2009). Inhibition represents the capacity to reduce interference by semantically strong related representations and thus facilitates the activation of semantically remote concepts. Furthermore, significant updating ability or working memory capacity enables the supervised search and manipulation of a larger number of representations. The authors interpret their findings as an indication that individuals with significant working memory capacity are able to perform more effective long-term memory searchs. This enables them to retrieve semantic concepts relevant to the problematic situation, which are required for generation ofcreative ideas.

However, although Benedek, Konen and Neubauer (2012) do explain the contribution of working memory they leaved unexplained the parameters outlining individual choice of creative strategy. In other words, they did not explain what determines at working memory level the relevant semantic concepts. This question is investigated in the present thesis where evidence suggests that creativity and working memory are in a constant dynamic relationship. Furthermore, the authors conclude that:

> People with higher working memory capacity may more easily keep all goals active throughout the task, whereas people with lower working memory capacity may fall back on less specific goals (for example, generating uses that are retrieved from memory and thus are likely uncreative) (p. 79).

This conclusion lends support for the indea that creative individuals can switch between strategies according to the required task (Gilhooly, Fioratou, Anthony & Wynn, 2007). Finally, the analysis reveals that the factor of personality reduces the observed relationship between creativity and intelligence, indicating that updating ability represents the central executive mechanism underlying the correlation of intelligence and creativity. The importance of the target task which was taken into consideration in

experiments related to this thesis, is in fact noted by Benedek, Konen and Neubauer (2012) as being a major limitation of their study:

> A few limitations of the present study should be acknowledged. First of all, this study used latent variables of executive functions, which were each defined by three task blocks of a relevant executive task, but not by different tasks of the same construct (p. 80).

The study conducted by Lee and Therriault (2013) provides significant findings indicating that creativity consists of distinct higher order cognitive processes including working memory processes. Using structural equation modeling the authors of this study attempt to investigate the relationships between intelligence, working memory, and three fundamental creative processes: associative fluency, divergent thinking and convergent thinking. For their assessment they elaborate various tasks. Creative thinking tasks are divided into three categories according to the three assumed cognitive processes underpinning creativity; associative fluency tasks (letter fluency task and category fluency tasks), divergent thinking tests (Guilford's unusual uses tests and the abbreviated torrance test for adults) and convergent thinking tests (RAT and insight problems). Intelligence is assessed using Raven's Advanced Progressive Matrices and Weschler's Adult Intelligence Scale-Revised, Vocabulary. Finally, working memory is assessed using the symmetry span task and the backward digit span task. The use of the two last tasks solely for working memory assessment can be considered as the most significant weakness of this study as they do not incorporate any semantic processing and, most importantly, they do not require creative abilities.

Any study investigating the relationship between working memory and creativity that does not employ working memory tasks requiring creative abilities or solutions (Yeh, Lai, Lin, Lin & Sun, 2015) is at a significant disadvantage. This is especially true in respect to previous experimental findings indicating that working memory and creative thinking share higher order processes (Baddeley, Hitch & Allen, 2009). The direct examination of one executive function, working memory, on the cognitive functions of creativity in Lee and Therriault's (2013) study, reveals that the model does not meet the criteria for good fit (RMSEA = .05, CFI = .91, TLI = .89, SRMR = .05). In this study, working memory significantly predicted associative fluency and convergent thinking (γ = .47, .66, $p < .001$, respectively) but not divergent thinking ($\gamma = -.14$, $p = .34$). The authors, given some non significant parameters, then proceeded to a final structural model. In the combined model, working memory indirectly predicted all three creative processes through intelligence and associative fluency. In particular, working

memory significantly predicted IQ ($\gamma = .70$, $p < .001$), and indirectly predicted associative fluency, divergent thinking and convergent thinking ($\gamma = .59, .32, .54$, $p < .001$, respectively).

Lee and Therriault (2013) proceed to give three explanations regarding the effect of working memory on the underlying cognitive functions of creativity, associative fluency, divergent thinking and convergent thinking. In divergent thinking tasks, an individuals' working memory supports the production of various ideas and representations while selecting the most effective and ignoring the more obvious responses. Thus, divergent thinkers exhibit higher rates of inhibiting common responses and deliberate switching of retrieval cues, processes believed to engage to central executive component in working memory. This ability to switch between response categories has also been shown to predict better performance on divergent thinking tests (Gilhooly, Fioratou, Anthony & Wynn, 2007; Nusbaum & Silvia, 2011; Benedek, Konen & Neubauer, 2012). Regarding convergent thinking, as this is assessed by RAT tasks and insight problems, working memory contributes to avoiding standard but ineffective solutions to the referent problem. However, the authors failed to address the differences and similarities between convergent and divergent thinking in regard to the adopted strategy, perhaps due to the use of ineffective working memory tasks as the implemented working memory tasks demonstrate a lack of creative thinking characteristics.

Finally, Lee and Therriault (2013) conclude that associative fluency is positively affected by working memory, as individuals with high working memory abilities are able to attend to a wider set of semantic and taxonomic categories that are available via spread of activation. However, their experiments relating to working memory tasks do not allow a precise explanation of how this conclusion is reached, for the same reasons as those addressed above. Overall, the authors propose that the cognitive foundations of creativity, assisted by working memory, incorporate strategy selection, category fluency, mental disassembling of figures, alternating between ideation and evaluation, and breaking set in the face of interference (Gilhooly, Fioratou, Anthony & Wynn, 2007).

In summary, there is converging evidence that executive functions, and especially working memory, have a significant role to play in creative thinking (de Bot, 2012). A working memory buffer is required for creative thinking while the operation and storage of working memory affects creative problem solving. Individuals with high working

memory capacity are more likely to be successful at overcoming interference caused by automatic, unoriginal responses and also be more successful at using strategies to generate novel approaches and responses when faced with creative thinking tasks (Baddeley, 2007). Increasingly, researchers are coming to the conclusion, albeit sometimes indirectly, that working memory capacity exerts an influence on performance of creative tasks that necessitate cognitive flexibility and higher order rules, as well as conscious attention to, and manipulation of, a wide range of cues (Rastogi & Sharma, 2010). However, the main disadvantage of the studies discussed above is that the majority do not test their theories using working memory tasks requiring creative abilities or solutions (Yeh, Lai, Lin, Lin & Sun, 2015). In conclusion, there is need for further research into how creativity and creative strategies can affect the strategies incorporated in working memory processes.

4.2 The relationship between creativity task performance and working memory with regard to the speed of information processing

Although the experiments associated with the present study do not allow for analysis of a direct connection between creativity and the speed of information processing there is a body of literature that provides a stable foundation for linking creativity task performance and working memory on the basis of information processing speed (Lee & Therriault, 2013; Vartanian, Martindale & Kwiatkowski, 2007; Sub, Oberauer, Wittmann, Wilhelm & Schulze, 2002). Speed of information processing is nevertheless a significant characteristic of working memory (Baddeley, 2012; Kaufman, Kaufman & Lichtenberger, 2011; Gobet & Simon, 1996).

The cognitive process that could potentially establish links between creativity task performance and working memory is attention (Vartanian, Martindale & Kwiatkowski, 2007). Von Muhlenen, Rempel and Enns (2005) report that creative people are characterised by defocused attention that may facilitate “attentional capture”. They base their statement on findings indicating that creative people have more defocused attention than non creative people. The facilitation of “attentional capture” enables the individual to rapidly consider phenomenally irrelevant concepts as relevant and consequently to find the appropriate or novel solution to the problematic situation, or perhaps even to create the foundation for the emergence of such a solution. Defocused attention is considered to be directed by reduced cognitive inhibition. By “cognitive inhibition” we mean the mechanism of restricting the flow of information into the focus of attention. Reduced cognitive inhibition rapidly allows more information into the

focus of attention for processing. Literature provides support for this hypothesis indicating that creative individuals tend not to inhibit irrelevant information. As a result, creative solutions are more likely to emerge as attention is focused on various elements of information (Benedek, Konen & Neubauer, 2012; Carson, Peterson & Higgins, 2003; Peterson, Smith & Carson, 2002; Peterson & Carson, 2000)

Martindale's (1999) hypothesis is significant in regard to the issue of defocused attention. She notes that there is no stable disposition towards defocused attention and that rather it depends on task demands. According to her hypothesis, creative people are better at rapidly adjusting their focus of attention depending on task demands. Furthermore, this adjustment is automatic, or reactive, rather than one involving self-control. When creative individuals are requested to solve a problem, they allow themselves to defocus attention. This tendency makes the central task more susceptible to interference by seemingly irrelevant information, some of which may provide the building blocks for solutions.

It does have to be pointed out that this widening of attention has a measurable speed effect on working memory as it requires more time, slowing down processing towards the goal of the task. Alhough, in later stages of creative problem solving, performance benefits from the inhibition of irrelevant information and concentration on the task requirements and characteristics. Thus, we can say that concentration on task objectives speeds up overall performance. This notion is supported by neuropsychological studies (Vartanian, Martindale & Matthews, 2009; Vartanian, Martindale & Kwiatkowski, 2007). The literature provides findings based on EEG alpha wave activity (measure of cortical arousal) assessed when individuals perform creative tasks. Evidence indicates that creative individuals demonstrate lower levels of cortical arousal while being engaged in creativity tasks, against higher arousal during the intelligence test. In contrast, individuals with low performance in creativity measurements exhibit high levels of arousal in both creativity and intelligence tasks. These findings demonstrate that creative individuals exhibit defocused attention when engaged in creative production, but not otherwise. Therefore, the incorporation of different strategies according to the task and their characteristics in regard to creativity competence allows a stable foundation for the main hypotheses of the present study. These assumptions are also supported by the findings of a psychometric study conducted by Vartanian, Martindale and Kwiatkowski (2007).

Regarding research on remote associations and information processing speed, Vartanian, Martindale and Matthews (2009) report that individuals scoring highly in creativity can more quickly judge the relatedness of concepts than non creative individuals. In particular, their analysis reveals that people with higher divergent thinking ability are faster in judging whether two concepts are related or unrelated. Furthermore, they note that this can lead to a substantial advantage in the number of potentially useful relationships that could be assessed per unit of time. A significant finding of this study is the absence of correlation with IQ measurements. The results are interpreted in relation to a recently proposed model of creative cognition suggesting that creative people are faster in information processing under conditions of low ambiguity.

In a relevant study, Rossman and Fink (2010) argue that creative people judge the associative distance of unrelated words to be lower when compared to the judgments of less creative people. This may point to their higher ability in terms of noticing subtle associations between unrelated concepts.

Taken together, the findings of Vartanian, Martindale and Matthews (2009) and Rossman and Fink (2010) mean it is reasonable to conclude that creative people show advantages in evaluating the relationship of remote concepts. This may, in turn, eventually facilitate the discovery of associative links and result in a high ability of associative combination. In other words, these findings allow us to hypothesise a strong relationship between the substantial properties of working memory structures and creative strategies. The ability to judge relatedness between concepts rests on the working memory procedure of recalling information from long-term memory. Thus it is reasonable to suggest that the processes of episodic buffer as well as the central executive are highly related to the speed of judgments of relatedness between concepts (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012; Campoy & Baddeley, 2008).

Kaufman, DeYoung, Gray, Brown and Mackintosh (2009), on the other hand, suggest that associative learning ability can predict variance in general intelligence above and beyond the variance predicted by working memory capacity and processing speed. They define associative learning as “the ability to remember and voluntarily recall specific associations between stimuli” (p. 374). However, associative learning in this study was approached at a different level of complexity in comparison to Benedek, Konen and Neubauer’s study (2012). It was perceived as an executive process that incorporates more than the four associative processes explored in Benedek, Konen and

Neubauer's study (2012). In particular, Kaufman, DeYoung, Gray, Brown and Mackintosh (2009) report that individuals consciously and voluntarily remember associations rapidly. Thus, the authors conclude that different mechanisms are likely to be involved in explicit versus implicit associative learning. This allows us to indirectly assume that associative processing and creativity are partially dictated by explicit strategies. As a result, associative processing and working memory are both predictors of general intelligence. Kaufman, DeYoung, Gray, Brown and Mackintosh (2009) also note that both working memory and processing speed are predictors of intelligence.

These results are inconsistent with work done by Conway, Cowan, Bunting, Therriault & Minkoff (2002), who found that processing speed no longer predicted general intelligence after controlling for working memory. These scholars also report that working memory and associative learning appear to rely on different regions of the Posterior Frontal Cortex (Petrides, 1995; 2000; Petrides M., Alivisatos, Evans & Meyer, 1993), and that processing speed seems likely to be determined by a distinct set of biological parameters. However, it should be pointed out that the sample size of this study was relatively low, raising questions about the gravity of the findings. The authors themselves note that "only one working memory task of multiple associative learning tasks is in use, creating a model that is slightly unbalanced in the number of markers for each of our three predictors, with the most markers for associative learning" (Kaufman, DeYoung, Gray, Brown & Mackintosh, 2009, p. 380).

In summary, the literature provides a stable foundation for indirectly linking creativity task performance and working memory on the basis of information processing speed (Lee & Therriault, 2013; Vartanian, Martindale & Kwiatkowski, 2007; Sub, Oberauer, Wittmann, Wilhelm & Schulze, 2002). The ability to judge relatedness between concepts, and consequently creative processes, rests on the working memory procedure of recalling rapidly information from long-term memory. Thus, it is reasonable to suggest that the processes of the episodic buffer as well as the central executive are closely connected to judgments of relatedness between concepts (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012; Campoy & Baddeley, 2008). Therefore, creativity and speed of information processing are linked on the basis of working memory. The incorporation of different strategies according to the task and their characteristics in regard to creativity competence establishes a stable foundation for the main hypotheses of the present study. We can assume that creative individuals process and apply different strategies according to the tasks they perform. As creative

competence decreases so too the possibility of incorporating different strategies declines.

5. Methodology of the experiment

5.1 Rationale of the study and main hypotheses

Working memory is a limited capacity system and the applied strategies in free recall tasks are determined by the individual differences and the specific requirements of the referent task (Baddeley, 2012; Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015).

Research into working memory and, more specifically, into item recall has shown that both items and words are more easily and successfully recalled when they are all drawn from the same semantic category (for example, all the items of the list are musical instruments or animals) (Baddeley, 2007). Verbal information encoding in working memory tasks is a consequence of automatic and/or controlled, attention demanding mechanisms of strategic retrieval and encoding (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Research on the retrieval of verbal items supports the distinction between a fast, automatic activation of mainly phonological or partially semantic representations and a slower, more controlled, and effortful mechanism of deep semantic strategic retrieval (Whitney, Grossman & Kircher, 2009; Gold et al., 2006; Badre & Wagner, 2002). A few studies have further demonstrated that switching between phonological and semantic encoding and recall is possible and observable (Hanley & Bakopoulou, 2003; Gilhooly, Fioratou, Anthony & Wynn, 2007). Thus, in groups of semantically related words it is very likely for the effect of an automatic phonological strategy to be reduced or abandoned in favor of a crystalised semantic strategic retrieval as the relationship between the items has already been learned and applied (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015).

In contrast, in relation to the characteristics of the general population, in groups of semantically unrelated words the most obvious and generally adopted strategy is reliance on phonological encoding (Baddeley, 2007). According to the multicomponent model of working memory, phonological encoding is the main and relatively automatic mechanism in verbal working memory. The absence of contextual semantic support characterises most standard working memory tasks involving the presentation and recall of lists of semantically unrelated words. For lists of semantically unrelated words an alternative strategy to the typical phonologically based strategy, is a more controlled and effortful mechanism of semantic strategic retrieval.

However, there are still contradictions over the question of which type of strategy (phonological, automatic or controlled semantic) is applied in specific tasks as well as

their effect gravity (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). Furthermore, individual differences can potentially play a significant role in terms of the selection of the most effective strategy. It is also reasonable to apply this distinction to working memory, suggesting that the creative strategies that underpin creative behaviour might have also a significant effect on encoding and recall processes.

This framework has led to inconsistencies in the literature and the development of different assumptions about the strategies employed in working memory processes. The main reason provided for the existence of interpretation differences in verbal short-term memory literature is in terms of the adopted strategies, phonological or semantic (Campoy & Baddeley, 2008). Although the use of a phonological strategy for recalling verbal information is considered predominant, under certain conditions or population characteristics the use of phonological strategy is partially abandoned in favour of a more reliable semantic strategy. There are also a number of instances of theoretically important results in which major inconsistencies appear to have resulted from switching between phonological encoding and another strategy, probably semantic (Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996). For example, as mentioned above, in groups of semantically unrelated words the most obvious and generally adopted strategy is reliance on phonological encoding. In such a situation automatic semantic activation is not sufficient and a controlled semantic strategic retrieval is not likely to be adopted. However, in groups of semantically related words the effect of an automatic phonological strategy is likely to be reduced or abandoned in favour of a semantic strategic retrieval. Studies conducted by Campoy and Baddeley (2008), Hanley and Bakopoulou (2003) and Logie, Della Sala, Laiacona, Chalmers and Wynn (1996) clearly indicate that the switch between phonological and semantic strategies is a standard phenomenon in verbal short-term memory tasks.

The ability of a subject to switch between a phonological and a semantic strategy relies on the characteristics of the task, the instructions provided and individual differences among the participants. A closer examination of the employed strategies during working memory tasks is therefore a significant factor that could affect not only the performance but also more importantly the quality of the working memory process outcome. It is important to remember the effects of this process on the organization of long-term memory representations and strategies, especially when we consider the significance of the collaboration between long-term memory and working memory (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). Furthermore, there is

a need for further investigation into the distinction between automatic and controlled strategies (Hanley & Bakopoulou, 2003). To date, as discussed above, there have only been a few studies that have sought to evaluate either the effect of switching between phonological and semantic strategies or the distinction between automatic and controlled strategies.

Relevant literature provides a good foundation for us to assume that semantic encoding in working memory tasks could possibly rely on strategic mechanisms, either automatic or controlled (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). However, there are contradictions over the question of which type of strategy (automatic or controlled) is more commonly applied in relation to specific tasks as well as their effect gravity. These dichotomies are mainly due to the different characteristics of the measurement methods used in previous evaluations. As Miyake, Friedman, Emerson, Witzki, Howerter and Wager (2000) point out, any evaluation of the employed strategies used in working memory tasks has specific weaknesses derived mainly from the individual differences spectrum. They see the existence of differences in the employed strategies not only between subjects but also within the same subjects, not only in relation to different tasks but even within the same task, stating:

> complex executive tasks tend to suffer from relatively low internal and/or test–retest reliability. Although the reasons for the low reliabilities are not completely clear, one possibility is that people adopt different strategies on different occasions (or even within a session) when performing these tasks. Also, the involvement of executive control functions is generally considered strongest when the task is novel (p. 53).

Such findings indicate that the use of automatic or controlled strategies in working memory relies not only on the characteristics of the task under assessment but also more importantly on relevant individual differences factors. Thus, an individual's abilities in terms of associative processing, or the ability to form or recall associations between items, is highly related to creativity. Associative processing is one of the main cognitive processes in creative thinking (Lee & Huggins, 2014).

Associative processing is the activation of mental networks consisting of objectively and subjectively associated concepts or mental items. In relation to creativity, the emergence of a creative product requires the activation of associations that are not commonly observed in the general population. This is achieved when a stimulus cues a semantic representation which in turn activates another mental item until the activation reaches the appropriate/effective association (Brophy, 2001). In

other words, creative ideas occur when more uncommon elements in lower position in the associative hierarchy are generated or activated. Alterntively, a more analytical reflection of associative processes in creativity research is that creative products or ideas are generated through the recombination of existing elements.

While few studies have directly investigated the relationship between working memory and creativity, some researchers propose that working memory capacity influences performance in relation to certain creative tasks. That is, those that necessitate cognitive flexibility, higher order rules, and conscious attention to, and manipulation of, a wide range of cues (Rastogi & Sharma, 2010). The majority of studies in this area suggest that working memory capacity is considered as a prerequisite for creativity generally and, more specifically, for cognitive flexibility, abstract thinking, strategic planning and processing speed in long-term memory (Deitrich, 2004). Further, a working memory buffer is required for creative thinking and the operation and storage of working memory affects creative problem solving. Individuals with high working memory capacity are more likely to be successful at overcoming interference caused by automatic, unoriginal responses and also be more successful at using strategies to generate novel approaches and responses in relation to creative thinking tasks (Baddeley, 2007). Thus a working memory buffer benefits creativity by enabling the individual to maintain attention to the task and preventing undesirable mind wandering (De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012).

Indirect support for the association between working memory and creativity comes from neuropsychological and medical studies. For example, it is now known that Ritalin (methylphenidate) administration significantly decreases symptoms of attention deficit hyperactive disorder (Swartwood, Swartwood & Farrell, 2003) while improving working memory and creativity. However, in terms of the present thesis, the main disadvantage of studies such as this is that they do not routinely employ working memory tasks requiring creative abilities or solutions (Yeh, Lai, Lin, Lin & Sun, 2015).

Although there is no research yet investigating how creativity can affect the strategies incorporated in working memory processes, we can make some assumptions indirectly based on relevant tangential research. For example, it has been found that selective attention, which involves the ability to focus cognitive resources on information relevant to goals, influences working memory performance (Gazzaley & Nobre, 2012), while both modality dependent working memory mechanisms and modality independent attention control mechanisms demonstrate an impact on insight

problem solving (Chein & Weisberg, 2013). Furthermore, Lee and Therriault (2013) link working memory prerformance with the underlying cognitive mechanisms of divergent, convergent thinking as well as associative processing.

As demonstrated above, there are significant gaps in the literature in terms of examining how creativity and creative strategies are related to the strategies incorporated in working memory processes identifying and filling those gaps is the main objective of the present thesis. Using the methodology of applying working memory tasks requiring creative abilities or solutions, combined with analyses of typical assessments of creativity and verbal working memory tasks, this thesis aims to both identify and then fill these gaps in scholarship. The present study therefore collected data relating to the participants' demographic information, performance on RATs and working memory performance from two different immediate free recall tasks. The first immediate free recall task contained semantically similar words while the second immediate free recall task used semantically dissimilar words. The implementation of two different tasks involving item recall allowed the observation of participants' performance in tasks requiring different strategies.

In summary, the reviewed literature reveals the need to find answers for specific questions in terms of the relationship between working memory and creativity:

- What are the characteristics of the relationship between working memory and creativity?
- Is the relationship between working memory and creativity task dependent? Research on working memory indicates that performance depends on the characteristics of the task and the employed strategies.
- Are creative strategies elaborated in working memory processes?
- Do creative individuals employ creative strategies during specific working memory tasks?

These questions along with the theoretical and empirical evidence of the relevant literature scaffold the main hypothesis of the present study:

- Creative individuals are able to employ different and controlled strategies in working memory processing according to the special characteristics of the referent task.

The rationale of the present experiment is based on the hypothesis that working memory is a limited capacity system and the applied strategies in free recall tasks are determined by the individual differences and specific requirements of the referent task (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012). In the implemented free recall task containing semantically dissimilar items the employed strategy, or the easily accessed common semantic ground of the task, are instantly available. There is no need for significant capacity resources. Thus, the employment of creative strategies is suppressed in favour of more economic solutions (Takeuchi et al., 2011). A solution is considered economic when there is minimal demand for working memory capacity and resources, and the required processing or recalling time is significantly reduced (Tse, 2009; Conway, Cowan, Bunting, Therriault & Minkoff, 2002). In a free recall task containing semantically dissimilar items, there is no obvious available solution to the problematic situation other than the phonological properties of the presented stimuli. In such a situation alternative strategies should be elaborated.

Individuals with sufficient creative abilities have a significant advantage due to their thinking strategies, tendencies or problem solving characteristics. All of these things allow them to operate more efficiently. Although it must be noted that this is not without cost. An extended amount of information flows into working memory and as a consequence these individuals have to sacrifice more time and resources in order to cope with the selected strategy (Baddeley, 2012). However, the end product of such a strategy is more efficient than a strategy which only depends on the phonological properties of the presented stimuli. Regarding the abilities of individuals to employ creative strategies in working memory tasks, Nusbaum and Silvia (2011) propose that creative people are more successful at overcoming interference caused by automatic, unoriginal responses, and therefore, are more successful at using strategies to generate efficient and novel responses. Also, Gilhooly, Fioratou, Anthony and Wynn (2007) argue that the ability to switch strategies determines the level of creativity competence and significantly affects the working memory processes. In other words, the active maintenance of any strategy, and especially a creative strategy, is closely related to executive functions and specifically working memory. However, these studies do not clarify what determines the choice of the appropriate strategy and whether any strategy could be employed during any working memory functioning. The selected methodology of present study allows not only the switch between strategies but also their observation. These questions will be analytically addressed by the findings of the present study.

The main hypothesis of this study was tested using three separate methods to analyse the collected data. Two of these methods tested the hypothesis directly while the third tested it indirectly. The first method involved the calculation of a bivariate correlation test, Pearson's Product Moment Correlation (Pearson's r), while the second referred to the statistical method of Partial Correlation – Pearson's r. The third was again a bivariate correlation test, Pearson's Product Moment Correlation (Pearson's r).

The first method required the calculation of the difference between the participants' performance in two conditions of immediate free recall task. In particular, for each participant the mean difference between performances using lists containing semantically similar items and lists containing semantically dissimilar items was calculated. The calculation of this difference reflected to what extent the participants used different strategies in different working memory tasks. By calculating the difference in performance between the two tasks, two tendencies were observed. Firstly, the difference could be large, indicating that there were no attempts to use recall strategies based on the semantic properties of the items (for example, the mean of performance on lists containing semantically similar items — 6/8 — versus the mean of performance on lists containing semantically dissimilar items — 3/6 — the difference is 3). Secondly, the difference could be small, reflecting that there were attempts to use recall strategies based on the semantic properties of the items (for example, the mean of performance on lists containing semantically similar items — 6/8 — versus the mean of performance on lists containing semantically dissimilar items — 4.5/6 — the difference is 1.5). Thus, in order to test the main hypothesis of this study it was necessary to calculate the degree of correlation between the aforementioned difference and the participants' score in terms of a creativity test (RAT).

The aim of the second technique was an attempt to discover the association between the assessed creative abilities and the working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items). However, the effect of participants' performance in tasks which facilitated the employment of automatic/common recall strategies (condition of semantically similar items) had to be taken out. Therefore, a Partial Correlation – Pearson's r was applied.

The third technique involved the comparison of the results of the second technique (a correlation between the condition of semantically dissimilar items and creativity score with partialling out the effect of the condition of semantically similar

items) with the results of the same correlation, but without taking out the effect of the third variable (condition of semantically similar items).

Further, to the test of the main hypothesis, additional analyses were carried out in order to investigate two general tendencies observed in the literature. In particular, the first tendency was the performance difference between lists containing semantically similar items and lists containing semantically dissimilar items. This analysis was performed in order to compare the findings of the present study with other studies investigating the differences between lists of semantically similar and dissimilar items (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012; Saint-Aubin, Ouellette & Poirier, 2005). The second tendency was the correlation between working memory performance in lists containing semantically similar items and creativity performance. This analysis allowed the establishment of the assumption indicating that in well known or simple tasks (less demanding) there is no (at least obviously observable) or even negative effect of creativity (Yeh, Lai, Lin, Lin & Sun, 2015).

5.2 Participants

The sample of the research was representative of Greek monolingual adults studying or having studied in a Greek university. Data was collected from a total of 276 participants. The sample consisted of 129 males and 147 females. Table 3 presents the demographic breakdown of the sample in percentages with regard to gender. For the performed statistical analyses the total number of participants is considered sufficient (Anastasi & Lee, 2016; Anastasi & Urbina, 1997). A total number of 279 replies on the survey were received. However, three responses were excluded from the analysis as they were not appropriately completed, that is, a significant number of replies were not provided. Participants completed the survey in one session, which lasted approximately 40 minutes. Special consideration was given to participants with special cognitive deficits. However, there was no need to exclude any replies as none of the participants reported any cognitive deficits. The sample is considered representative as the major universities in Greece have students from different areas of Greece (cencus 2010). This parameter secures that the sample was balanced according to socioeconomic perspectives.

The average age of the sample was 25.33 years (SD = 2.1). Participants were allocated into four groups according to their age. The five groups included the following age ranges: 18–25, 26–30, 31–35, 36–40 and over 50. The demographic characteristics of the sample with regard to age are presented in Table 4. According to the academic

qualifications of the participants they were allocated into seven groups. The seven groups included the following categories: secondary education, tertiary education student, tertiary education (for example, BSc, BA) graduate, postgraduate student, postgraduate title, PhD and other. The demographic characteristics of the sample with regard to their academic qualifications are presented in Table 5. The participants' recruitment was divided into two phases. During the first phase a pilot study was carried out in which 30 students participated. The number of the participants in the pilot study was considered satisfactory on the basis of the psychometric properties of the constructed tests (the number of the factors that was used) according to the classical theory (Alexopulos & Kalaitzidis, 2004). Since the results of the pilot study were satisfactory, the second phase then commenced. The participants of the study remained anonymous during the whole phase of the survey and their participation was voluntary. The administration of the tests complied with the standards held by the Greek ministry of education and Macquarie University. In particular, it was compulsory that the participants be provided with a consent form signed by the investigator. The study also required ethical approval from the investigator's institution (Macquarie University).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	129	47.1	47.1	47.1
	Female	147	52.9	52.9	100.0
	Total	276	100.0	100.0	

Table 3. Demographic breakdown of the sample in percentages with regard to gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Age range	18–25	182	65.1	65.1	65.1
	26–30	74	27	27	92.1
	31–35	17	6.2	6.2	98.3
	36–40	3	1.7	1.7	100
	over 50	0	0	0	
	Total	276	100.0	100.0	

Table 4. Demographic breakdown of the sample in percentages with regard to Participants' age group

		Frequency	Percent	Valid Percent	Cumulative Percent
Academic qualifications	Secondary Education	0	0	0	0
	Tertiary Education Student	159	57.3	57.3	57.3
	Tertiary Education (for example, BSc, BA) Graduate	24	7.7	7.7	66
	Postgraduate Student	64	23.4	23.4	89.4
	Postgraduate title	11	4.1	4.1	93.5
	PhD	18	6.5	6.5	100
	Other	0	0	0	
	Total	276	100.0	100.0	

Table 5. Demographic breakdown of the sample in percentages with regard to Participants' academic level

5.3 Design

With regard to working memory performance, data from two different tasks of word recall was collected. The first task contained semantically similar words while the second task contained semantically dissimilar words. Participants' performance on RATs was also recorded as well as demographic information. In order to assess the main hypothesis of the study the difference between the conditions was calculated: lists of semantically similar items and lists of semantically dissimilar items.

As the main hypothesis, that creative individuals employ creative strategies during working memory processing, was to be tested both directly and indirectly, three different experimental designs were elaborated. The two of them tested the hypothesis directly while the third tested it indirectly. The first technique involved the calculation of a bivariate correlation test, Pearson's r, the second referred to the statistical method of Partial Correlation – Pearson's r. The third was again a bivariate correlation test,

Pearson's r. Additional analyses were performed in order to investigate the observed difference in multiple studies (for example, Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999) between working memory performance in terms of semantically related words and semantically unrelated words. A further analysis was performed in order to test the possible relationship between creativity and participants' performance in terms of working memory recall using lists containing semantically similar items. The aforementioned aims of the study scaffold the following experiment designs.

The first experiment testing the main hypothesis was a relational (Robson, 2002)/bivariate correlational (Dancey and Reidy, 2002) fixed design, which measured the degree of association between creativity processes abilities and the second variable, the calculated difference between working memory performance on semantically similar and dissimilar words. The experiment was a cross sectional design because all measures were taken at the same time. The research question was formulated prior to the data collection: is there any correlation between creativity processes and the difference between working memory performance on semantically related and non related words and, if such an association exists, is it significant? Any causation between those two explanatory variables was not predicted or assumed; moreover this is beyond the scope of this research.

The second experiment involving assessment of the possible correlation between creativity process performance and working memory performance in terms of immediate free recall tasks containing semantically dissimilar words, is a partial correlational (Dancey and Reidy, 2002) fixed design, which measured the degree of association between creativity process abilities and the second variable, working memory performance (as estimated by the number of correctly recalled words) on semantically dissimilar words. This was a cross sectional design because all measures were taken at the same time. The correlation between the two aforementioned variables was calculated while controlling for the working memory performance in tasks not requiring the employment of creative recall strategies, in order to achieve efficient performance (condition of semantically similar items). The research question was formulated prior to the data collection: is there any correlation between creativity process abilities and working memory performance on semantically dissimilar words and, if such an association exists, is it significant? Any causation between those two

explanatory variables was not predicted or assumed; moreover this is beyond the scope of this research.

Finally, the results of the Partial Correlation – Pearson's r analysis were compared with an additional bivariate correlation test, Pearson's r, between scores on the creativity test (RAT) and the working memory performance in tasks requiring the employment of creative recall strategies, in order to achieve efficient performance (condition of semantically dissimilar items). The experiment involving the indirect assessment of possible correlation between creativity process performance and working memory performance in an immediate free recall task containing semantically disimilar words, is a relational (Robson, 2002)/bivariate correlational (Dancey and Reidy, 2002) fixed design, which measures the degree of association between creativity process abilities and the second variable, working memory performance (as was estimated by the number of correctly recalled words) on semantically dissimilar words. This was also a cross sectional design because all measures were taken at the same time. The research question was formulated prior to the data collection: is there any correlation between creativity processes abilities and working memory performance on semantically dissimilar items and, if such an association exists, is it significant? Any causation between those two explanatory variables was not predicted or assumed; moreover this is beyond the scope of this research.

An additional analysis was performed in order to indirectly test a possible correlation between scores on a creativity test (RAT) and scores on lists containing semantically similar items. For this assessment the experiment was a relational (Robson, 2002)/bivariate correlational (Dancey and Reidy, 2002) fixed design, which measured the degree of association between creativity process abilities and a second variable (participants' working memory performance on semantically similar words). The experiment was a cross sectional design because all measures were taken at the same time. The research question was formulated prior to the data collection: is there any correlation between creativity processes and participants' working memory performance on semantically similar words and, if such an association exists, is it significant? Any causation between those two explanatory variables was not predicted or assumed; moreover this is beyond the scope of this research.

In regard to assessment of the expected difference between working memory performance in relation to semantically similar words and semantically dissimilar words, the experiment was (2X2X2) factorial three way mixed analysis of variances.

The dependent variable was the participants' performance on the working memory tasks. Specifically, the number of correctly recalled words generated the mean of the participant's performance. As noted above, the working memory tasks did not require serial recall but rather free recall, thus allowing for the emergence of creative strategies. Therefore, in each condition the maximum mark that could be obtained was 8 and the minimum was 0.

The participants' gender was the between participants factor (the factor of gender was included in the analysis in order to confirm the prediction supported by the literature that it has no significant effects on the data) . This factor had two levels: (1) female and (2) male. The type of provided information with regard to semantic similarity was the first within subjects factor. This factor had two levels: (1) semantically similar words and (2) semantically dissimilar words. The second within subjects factor was the grammatical category of the presented words and it had two levels: (1) nouns and (2) verbs. Therefore, each participant was assessed in four conditions. Each participant received all the experimental items. The four conditions were analytically as follows: (1) semantically similar nouns, (2) semantically dissimilar nouns, (3) semantically similar verbs and (4) semantically dissimilar verbs.

For the establishment of the reliability and the validity of the experimental manipulation used a pilot study was carried out and an analysis performed prior to the main data collection. This enabled correction of the observed mistakes. All the standard proposed methods for evaluation of the assessment tools were performed. For both the standardised and adapted for the Greek population test (RAT) no statistical analysis was performed in order to establish its validity and reliability. That was because this test is adapted and extensively used. Finally, analysis of the data was done using the statistical programme for social sciences (SPSS XI).

5.4 Materials

The survey was carefully designed in order to collect general demographic information from the participants. Furthermore, an adapted version of the RAT for the Greek population was used for the assessment of creative abilities. Verbal working memory performance of the sample was assessed by a replicated experimental manipulation. The aforementioned data collection tools were elaborated in order to secure a reliable and valid assessment.

The RAT was used for the assessment of creative abilities. This test was selected because it is a standardised test for the Greek population and has been used extensively in the literature in terms of assessing creativity (Lee & Huggins, 2014; Sternberg, 2003). Additionally, the RAT was chosen instead of constructing an entirely new assessment tool because this enabled a level of compatibility with results from previous studies.

In terms of the experiment for assessing verbal working memory performance, the design of the stimuli as well as the procedure of word allocation and previously applied methods were replicated (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015; Larigauderie, Michaud & Vicente, 2011; Campoy & Baddeley, 2008; Martin, 2005; Haarmann & Usher, 2001; Walker & Hulme, 1999; Poirier & Saint-Aubin, 1995). The use of the methodology discussed above, in conjunction with the statistical analyses, enhanced the validity and reliability of the assessment tool.

In summary, 28 sets (each consisting of eight words) of semantically related and unrelated items were presented in a fixed time to the participants. After the presentation of each set, the participant was asked to recall as many words as possible in any order (free immediate recall task). The same procedure was followed for the semantically related and unrelated items. The most significant point of the adapted experiment was the elaboration of working memory tasks that contain a problematic situation highly linked to creativity. Previous studies that focused on exploring the relationship between working memory and creativity generally used working memory tasks that were not related to creativity tasks (Yeh, Lai, Lin, Lin & Sun, 2015; De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012). The inclusion of these characteristics in the present study allowed the emergence of significant and insightful findings regarding the foundations of the relationship between working memory and creativity.

5.4.1 The Remote Associates Test (RAT – Greek)

The RAT is a creativity test used to determine a person's creative potential. It is a test of creative thinking capacity and was developed initially by Mednick (1962, 1968). Each RAT problem or question requires the individual to provide a solution word that is related to the three cue words presented. The problems/questions are designed so that the solution word is not a strong — that is, frequent — associate to any cue word. Thus, each possible solution requires that the individual search through long-term memory to find unusual or infrequent associations. For example, when the cue words "age, mile and sand" are presented the participant must discover their common associate, for

instance, “stone” (stone age, milestone and sandstone). Solving a RAT problem/question requires the individual to think outside the box. Deriving remote associations for the cue words requires that the person break away from the dominant or high frequency/automatic associations produced by each cue word (Mednick, 1962; 1968).

The standardised RAT in Greek (RAT – Greek) used in the present study has been tested for its validity and reliability, and its psychometric properties are accepted (Koromvokis & Kalaitzidis, 2014; Alexopoulos & Kalaitzidis, 2004). It consists of ten questions. Prior to the administration of the main RAT four practice trials were also included. The RAT – Greek was comprised of 30 words distributed into ten problems/questions (see Appendix 1). Items were categorised as easy (70% or above success rate), average (30% to 70% success rate), or difficult (30% or lower success rate). The 30 RAT items in this study were selected from these three categories to represent a range of easy to difficult items in the test. The four practice trials consisted of items derived from the easy category. All of the items were presented randomly in order to prevent any effect attributed to the factor of increased difficulty. The instructions and the tasks were presented in Greek. The implemented score on the RAT – Greek represents the total number of correct solutions.

The psychometric characteristics of the RAT with regard its ability to measure creativity abilities are discussed above. In summary, there is sufficient evidences for the ability of the RAT to measure convergent/associative thinking and, consequently, creativity. The categorisation of convergent/associative thinking under the cognitive processes of creativity is evident mainly because the process of convergent/associative thinking allows the generation of novel and appropriate solutions (Kaufman, Kaufman & Lichtenberger, 2011; Treffinger, Isaksen & Dorval, 2002; Brophy, 1998). Mednick (1962), who originally created the RAT, explains the link between convergent/associative thinking and creativity by proposing that more creative individuals have flatter associative hierarchies that support the activation and combination of more distally related elements in the mental network. Therefore, more creative individuals who are better able to find a mediating link between seemingly unrelated words are expected to show superior performance on the RAT. This in turn connects convergent thinking with associative processing and divergent thinking (Lee & Huggins, 2014; Lee & Therriault, 2013). Finally, the importance of the RAT as a reliable tool in measuring creativity is revealed by the existence of convergent thinking

processes in divergent thinking, which is one of the main alternative measurements of creativity. This is also supported by research findings indicating the importance of associative abilities in both convergent and divergent thinking (Benedek, Konen & Neubauer, 2012).

5.4.2 Immediate free recall task — verbal working memory performance assessment

The participants' working memory abilities were measured using an experimental manipulation: an immediate free recall task was used to assess verbal working memory performance. The participants were presented with one list of items in each trial. Immediately following the presentation of the list the participants had to recall the presented items in any order. Each list consisted of eight items (see Appendix 2). The number of syllables of the words in each list was balanced, four words had three syllables while four words had four syllables. The total number of letters in each list remained constant.

The 28 sets of items were divided into two categories with regard to their semantic characteristics. Fourteen semantically similar lists were assembled. Each list was comprised of eight words drawn from the same semantic category (for example, music, food or school). The 14 sets were also divided into two categories with regard to their grammatical category, seven lists were comprised of nouns and seven of verbs. Finally, the rest of the 14 lists were comprised of semantically unrelated items. Each list also was comprised of eight words drawn from different semantic categories. Each word in the semantically unrelated list had to come from a distinct semantic category, strictly avoiding any overlapping between semantic categories. As in the list of semantically related items, the 14 sets of items the semantically unrelated lists were also divided into two categories with regard to their grammatical category; seven lists were comprised of nouns and seven of verbs. In total, for the immediate free recall task, 224 items were created.

Each word was used only once, either in a semantically similar list or in a semantically dissimilar list. With regard to the number of syllables, the three syllable words and four syllable words were presented in interchanged serial positions. In addition, in both similar and dissimilar lists, care was taken to avoid phonological similarity by not including words that rhymed or shared the first syllable. All the selected words were concrete in order to avoid the concreteness effect (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Prior to the main immediate free recall task four practice trials were included. The constraints of the main immediate free recall

task, outlined above, were applied to the four practice trials. Thus, these four practice trials were comprised of two semantically related lists and two semantically unrelated lists. The two semantically related lists consisted of one list of nouns and one of verbs. Similarly, the semantically unrelated lists consisted of one list of nouns and one of verbs. Participants completed the task within one session. The presentation was made on a computer and all signals and words were presented at the centre of the computer screen. The instructions, as well as the material of the experiment, were in Greek.

The selected words for both categories (semantically related and unrelated items) were common and not rare words. This decision was based on research findings regarding the mixed list paradox (list containing rare and common words). This paradox refers to the hypothesis that as rare words are encountered only infrequently this renders them more arousing or attention demanding and thus more recallable (Watkins, Kim & LeCompte, 2000). It is assumed that this principle is not applied, or is overridden by other factors, when rare words are presented en masse, and comes into play only when they are juxtaposed with common words, as in a mixed list procedure. What is not known is the precise nature of such a strategy. Perhaps the rare words are thought about more deeply or for a longer time than the common words. Regardless, it appears that the strategy is applied in at least some measure whenever it is anticipated that memory for the words will be tested. However, no claim is made for such memorisation strategies for tests other than free recall assessments (Watkins, Kim & LeCompte, 2000). In particular, there is no evidence that such strategies are adopted in preparation for a recognition test. Word recognition depends on the commonness of the word, although in contrast to free recall, recognition tends to be better for rare words (Saint-Aubin, Ouellette & Poirier, 2005). Therefore, as the purpose of this study was to investigate the possible effect of creative strategies, other effects, especially if they concern recall strategies, had to be eliminated or even excluded. Thus the adapted lists contained only common words.

An immediate free recall task was chosen instead of an immediate serial recall in order to allow the emergence of creative strategies in working memory. In an immediate serial recall assessment the participant has to recall the referent list in its presented order. In contrast, in an immediate free recall task, the participant may recall list items in any order, and the presentation order is randomised from trial to trial. The findings of Klein, Addis and Kahana (2005) indicate that presentation order is an important factor, causing participants to exhibit the same temporal associations in serial recall and free

recall with constant presentation order. In addition, given that associative processes play an important role in episodic memory (Kahana, 1996) it is reasonable to conclude that the choice of a free recall task was most appropriate task for working memory assessment instead of a complex immediate serial recall task allowing the emergence of creative strategies.

Furthermore, Bhatarah, Ward and Tan (2008) note that performance in tasks involving immediate serial recall and free recall is underpinned by common memory mechanisms. This hypothesis is supported by a study conducted by Poirier and Saint-Aubin (1995). The findings of this study are especialy important for the present thesis as one of the tested variables is the semantic similarity effect. The study, under the title "Memory for Related and Unrelated Words: Further Evidence on the Influence of Semantic Factors in Immediate Serial Recall" used four experiments to reveal a clear recall advantage for short lists comprising words from the same category, whether items were scored with a free recall or strict serial order criterion. The authors conclude that when order errors are scored together with item or content errors, the effect of semantic grouping is just as strong as when order errors are not taken into account. These results indicate that the effect depends on content errors much more than on order errors. Also, there was no similar disadvantage for the recall of order information. These results were confirmed by the third and the fourth experiments in the same study. The results of this study provide sufficient arguments and contradiction for the notion that semantic similarity hinders the short-term recall of order information. Therefore, the choice of a free recall task does not exclude any cognitive mechanism that is present in serial recall allowing, at the same time, more advantages

Finally, as already noted, the most significant dimension of the adapted experiment was the elaboration of working memory tasks that contain a problematic situation closely linked to creativity. Previous studies that have focused on exploring the relationship between working memory and creativity have generally used working memory tasks not related to creativity tasks (Yeh, Lai, Lin, Lin & Sun, 2015; De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012). The exclusion of this parameter has thus inhibited the emergence of important dimensions in terms of the relationship between working memory and creativity. The inclusion of these characteristics in the present study therefore allowed observations, in addition to the standard ones, on how semantic and creative strategies are implemented in working memory. The absence of these

parameters has also been pointed out in significant studies and identified as a possible source of future research (De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012)

5.5 Ethics approval — Consent form

As the survey was conducted in Greece under the supervision of an Australian university (Macquarie University) regulations and guidelines from both countries had to be taken into consideration. Before any data could be collected from the participants, the present research had to first comply with the National Health and Medical Research Council (NHMRC)'s Australian Code for the responsible Conduct of Research[1] (2007), the National Statement on ethical conduct in Human Research.[2] The study also had to comply with the relevant legislation and guidelines of the Hellenic Society for Ethics, the Hellenic General Office of Research and Technology, and the engaged Greek universities.

A detailed application describing the purpose and methodology of the present study and experiment was submitted and monitored by the Faculty of Arts Human Research Ethics Committee (Macquarie University). The final ethics approval for the study was obtained on 5 August 2015. A progress report was submitted to the Human Research Ethics Committee (Macquarie University) on 3 August 2016. Participation in the survey was voluntary and anonymous. The collected data are accessed only by the researchers stated on the ethical application, in accordance with the regulations of the Faculty of Arts Human Research Ethics Committee (Macquarie University). Furthermore all data has to be retained for a period of at least five years.

According to the relevant instructions each participant was provided with a consent form. The consent form was submitted to the Faculty of Arts Human Research Ethics Committee (Macquarie University) in two formats (Greek and English). However, as the participants were all Greek speakers they received only the Greek version in order to avoid any possible confusion. The consent form included information about the title, purpose and procedure of the experimental tasks. The participants were asked to consent to being involved in the study. They were also informed that participation or non-participation would have no bearing on their unit assessment. It was made clear that participation was voluntary and unpaid and that participants were able to withdraw from further involvement in the research at any time without consequence. Finally, all the contact details of the researchers and the

[1] www.nhmrc.gov.au/guidelines-publications/r39.
[2] www.nhmrc.gov.au/guidelines-publications/e72.

Macquarie University Ethics Committee were made available on the form. This provided the participants with the option to contact the researchers in order to receive information about the procedure and the outcome of the study.

The Ethics Application of the study is Ref: (520 150 048 9). The consent form provided to the participants is located in Appendix 3.

5.6 Procedure

Recruitment of the participants was performed according to the procedure approved by the Faculty of Arts Human Research Ethics Committee (Macquarie University). Academics as well as research committees from Greek universities were contacted and their support was secured. The academics distributed an email created by the researchers to individual students inviting them to participate in the study. The email can be found in Appendix 4. In the email, the participants were informed about the research and it was clarified that participation or non-participation would have no bearing on their unit assessment. It was also made apparent that involvement was voluntary and unpaid and that students were able to withdraw from further participation in the research at any time without consequence. All the necessary instructions, the consent form and the tasks, as well as a power point file, were attached to the email. The email, the consent form, the instructions and the material for the experiment and the task were all delivered in Greek.

After the completion of the consent form the participants preceded to the instructions. The first task that had to be completed was the RAT (RAT – Greek). Initially, participants had to complete four practice questions. Each practice trial began with the warning prompt "*Attention*" (1000 msec on). The practice question consisted of three cue words on the screen, followed by a blank screen that prompted participants to generate the fourth solution word. No time limit was imposed for the four practice items. Participants could proceed to the next trial when they felt that they were ready. Following the practice trial, participants completed the main questions of the RAT – Greek. Again, each question began with the warning prompt "*Attention*" (1000 msec on) at the centre of the display monitor. Each question consisted of three cue words appearing on the screen, followed by a blank screen that prompted participants to generate the fourth solution word. Participants were given 15 seconds per set of three cue words.

In terms of the second part of the survey, the immediate free recall task, additional instructions were provided. Initially, the participants had to complete the four practice trials. Each practice trial began with the warning prompt "*Attention*" (1000 msec on). Each practice trial consisted of eight words (the exact material used has already been described in the material section 5.4 above). At the practice trials both types of eight word sets were introduced. Thus, two practice trials contained semantically related words and two practice trials contained semantically unrelated words.

In terms of timing, the presentation rate of the stimulus was gradually decreased until the it reached the rate required for the main trials. Thus, the first practice trial had a presentation rate of 600 msec per word plus 20 msec for every letter in a word, while the second had a rate of 500 msec per word plus 20 msec for every letter. The third had a rate of 400 msec per word plus 20 msec for every letter and the fourth a rate of 300 msec per word plus 20 msec for every letter. The stimulus was presented at the centre of the display monitor. The eight word practice set was followed by a blank screen that prompted participants to recall as many of the presented words as they were able. There was no time limit for recall allowing the emergence of any controlled recall strategy.

Following the four practice trials, participants completed the main working memory task consisting of 28 trials. Each trial contained the following steps.

1. Each trial began with the warning prompt "*Attention*" (1000 msec on).
2. The stimulus (eight words) was presented at the centre of the display monitor. The stimulus presentation rate was stable at 300 msec per word plus 20 msec for every letter in a word. The two types of stimuli (semantically related words and semantically unrelated) words were interchanged randomly.
3. The eight word set was followed by a blank screen that prompted participants to recall as many of the presented words they were able. Again, there was no time limit for recall.
4. After every ten trials, there was a short one minute break, during which participants were asked to rest their eyes and then focus them at various distances.

Self-report questions related to participants' demographic characteristics as well as their tertiary education status were then filled out. The researchers received all the provided information anonymously and accompanied by a unique number. The purpose of the unique number was to allow the researchers and participants to track the information. The participants had the option to pause the survey at any point except for the period

between the presentation of the stimulus and the required answer for the first task or the word recall for the second task.

5.7 Pilot study

The generally acceptable methodology in psychological experiments is that it is necessary to perform a pilot study prior to the administration of the main tasks of a study. Therefore, prior to the commencement of this study a battery of tasks was administered to a sample of 25 participants. A qualitative analysis of the collected data from the pilot study revealed that the characteristics and the quality of the battery of the applied tasks were sufficient for the researchers to track any problems. Due to the small sample size the quantitative analysis of this data dictated the application of non-parametric tests. The analysis also revealed problems with three sets of words in the immediate free recall task. Specifically, the pilot study participants indicated that some of the implemented words in these sets resembled each other phonologically. These words were appropriately replaced and evaluated again prior to the commencement of the main study. No other issues emerged thereby allowing researchers to settle the design of the final experiment.

6. Results

6.1 Validity of the immediate free recall task and the RAT – Greek

According to accepted methodology, the validity of tasks used in research must be proven in advance. The applied RAT – Greek involves an adapted approach to the typical RATs that are broadly used in creativity research. Because of this broad application, there was no need to proceed to statistical analyses in order to ensure the good psychometric properties of the test.

However, the effectiveness of the immediate free recall task in terms of measuring and predicting the participants's verrbal working memory performance did have to be checked. A construct validity test of the immediate free recall task was considered the most appropriate technique for ensuring that the task measured what it was constructed to measure and did so efficiently. The construct validation performed proved that the theoretical approach employed in the construction of the task was appropriate.

6.2 Construct validity of the immediate free recall task

It was essential to establish the assumption of normality for recall accuracy in the immediate free recall task (Dancey & Reidy, 2002). This assumption was met. In particular, the Skewness and Kurtosis values ranged from 0.84 to 0.89.

The number of participants in the factor analysis was 276. The adequacy of the sample size is confirmed by both the Kaiser–Mayer–Olkin test of sampling adequacy and Bartlett's test of sphericity. The first was 0.84, which is considered a satisfactory value (Kaiser, 1994), and the second was also statistically significant (X^2 = 7170,54, df = 1, 276, $p < .05$). Loadings greater than 0.30 were considered to be significant.

In order to determine the efficiency of the task, a series of factor analyses were performed. Two, three, four, five and six factors were extracted. It appeared that the two factor solution was meaningful in order to extract the number of factors proposed by the relevant literature (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). In particular, the two factor solution coincided with the semantic characteristics of the selected items in each list/trial, as well as the experimental manipulations in prevous studies examining the semantic encoding in word recall (for example, Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Tse, Li & Altarriba, 2011; Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999). In this instance, the number of factors found was the same as in the assumptions for the experiment, that is, two factors (Factor 1 — semantically

similar items and Factor 2 — semantically dissimilar items). The scree test also showed the extraction of two factors (Cattell, 1966). In addition, a Principal Components Analysis was performed with oblique rotation using the Promax method as well as an orthogonal rotation with the Varimax method. The orthogonal rotation reached a simple structure. The two factors explained 34.07% of the total variance. The final factor matrix is shown in Table 6. Correlations greater than 0.30 or higher on each factor are shown in bold-face. Table 7 presents the eigenvalues and percentages of the explained variance.

	Factor loadings	
No of Item	Semantically related items	Semantically unrelated items
1 Semantically related list	**.74**	.22
2 Semantically related list	**.68**	.18
3 Semantically related list	**.59**	.21
4 Semantically related list	**.71**	.18
5 Semantically related list	**.72**	.19
6 Semantically related list	**.67**	.22
7 Semantically related list	**.54**	.25
8 Semantically related list	**.49**	.17
9 Semantically related list	**.70**	.19
10 Semantically related list	**.68**	.15
11 Semantically related list	**.42**	.08
12 Semantically related lit	**.71**	.16
13 Semantically related list	**.56**	.19
14 Semantically related list	**.75**	.09
15 Semantically unrelated list	.18	**.59**
16 Semantically unrelated list	.21	**.47**
17 Semantically unrelated list	.25	**.32**
18 Semantically unrelated list	.29	**.51**
19 Semantically unrelated list	.19	**.44**
20 Semantically unrelated list	.29	**.49**
21 Semantically unrelated list	.09	**.55**
22 Semantically unrelated list	.17	**.48**
23 Semantically unrelated list	.15	**.38**
24 Semantically unrelated list	.11	**.35**
25 Semantically unrelated list	.13	**.41**
26 Semantically unrelated list	.12	**.50**
27 Semantically unrelated list	.14	**.47**
28 Semantically unrelated list	.21	**.37**

Table 6. Varimax rotated principal component analysis for each of the 28 items of the two immediate free recall tasks

	Eigenvalues		
	Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %
Semantically related items	1.405	22.73%	22.73%
Semantically unrelated items	.730	11.34%	34.07

Table 7. Eigenvalues and percentages of the explained variance

Factor 1 accounted for 22.73% of the common variance after rotation. It consists of 14 items. All of the items have significant loadings, which range from 0.65 to 0.52. All of the items belong to the subdivision of semantically related items. Thus, Factor 1 can be labelled semantically similar items.

Factor 2 accounted for 11.34% of the common variance after rotation. It is composed of 14 items. The 14 items have significant loadings which range from 0.51 to 0.33 and all of these items belong to the subdivision of semantically unrelated items. Thus, Factor 2 may be called semantically dissimilar items.

Further, in order to establish the construct validity of the immediate free recall task, a confirmatory factor analysis was performed using AMOS 3.6 (Arbuckle, 1997), investigating the two factor model of the constructed task. The estimation method used was that of maximum likelihood. The following indices were used to assess the fit of the model to the data: the ratio of discrepancy, X^2, divided by the degrees of freedom (X^2/df); the goodness of fit index (GFI); the adjusted goodness of fit index (AGFI); the Tucker–Lewis index (TLI); the comparative fit index (CFI); the root mean square error of approximation (RMSEA); and the root mean square residual (RMR). It must be noted that there are no precise standards which indicate the values of the indices needed for a good fit. The analysis provided the following values for the aforementioned indices: X^2/df = 2.98, (GFI) = 0.81, (AGFI) = 0.79, (TLI) = 0.98, (CFI) = 1.07, (RMSEA) = 0.06 and (RMR) = 0.05. With regard to X^2 = df values fewer than three are considered favourable (Kline, 1998). Furthermore, the X^2 value was considered not as a formal statistic. Instead, it was suggested to informally compare the magnitude of an observed X^2 value to the degrees of freedom, and that a ‘small’ X^2 = df indicates a good fit and a large value indicates a ‘bad fit to the data’ (Mueller, 1996). Hu and Bentler (1999) reject

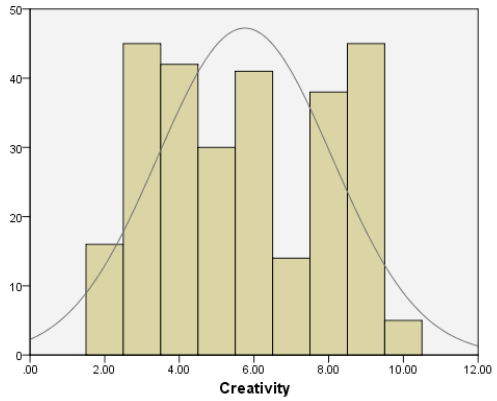
the indices GFI and AGFI as acceptable tests of fit. They believe that the minimum criteria for fit using the relative fit TLI and CFI index is at least 0.95 or higher. The RMSEA indicates a good fit if it is smaller, < .05, and the RMR indicates a 'good' fit if its value is small, <0.05 or below. Thus, we can conclude that the model seems to fit by all standards of fit, except the one index of RMSEA and the index of RMR. It also seems that the overall fit of the model of two factors is accepted (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005).

6.3 Descriptive statistics

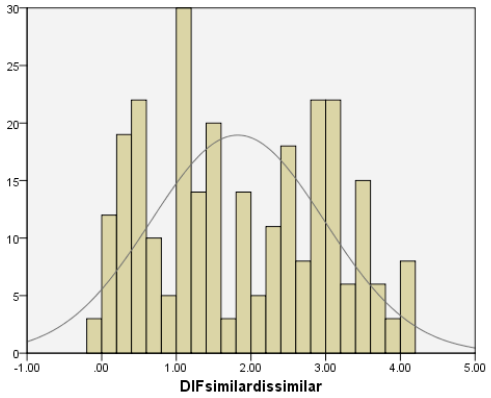
The scores from the immediate free recall tasks and RAT were decoded. These results were used to calculate the difference between participants' scores in terms of semantically similar lists and semantically dissimilar lists. Table 8 presents the number of participants, minimum and maximum scores, mean, standard deviation and variance for the conditions (semantically similar nouns, semantically similar verbs, semantically dissimilar nouns, semantically dissimilar verbs) and the calculated results: semantically similar lists, semantically dissimilar lists, creativity, difference between semantically similar lists and semantically dissimilar lists. Data was analysed using SPSS version 24. The descriptive statistics for: distribution of participants' scores on RAT; distribution of participants' scores on difference between semantically similar lists and semantically dissimilar lists; distribution of participants' scores on semantically similar nouns; distribution of participants' scores on semantically similar verbs; distribution of participants' scores on semantically dissimilar nouns; and distribution of participants' scores on semantically dissimilar verbs are presented in Graphs 1 to 6 respectively.

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Semantically similar lists	276	4.00	7.70	6.0199	.96306	.927
Semantically dissimilar lists	276	2.00	7.00	4.2047	1.23578	1.527
Creativity	276	2.00	10.00	5.7536	2.33023	5.430
Difference between Semantically similar lists and Semantically dissimilar lists	276	-.10	4.00	1.8225	1.16216	1.351
Semantically similar nouns	276	3.40	8.00	6.0163	1.06409	1.132
Semantically similar verbs	276	3.60	8.00	6.0087	1.03143	1.064
Semantically dissimilar nouns	276	2.00	7.30	4.1996	1.28749	1.658
Semantically dissimilar verbs	276	2.00	7.30	4.1928	1.28895	1.661
Valid N (listwise)	276					

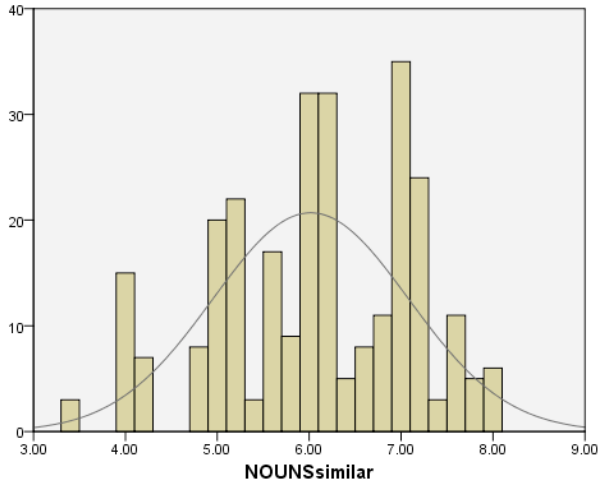
Table 8. Descriptive statistics. Number of participants, minimum and maximum score, mean, standard deviation and variance for the conditions (semantically similar nouns, semantically similar verbs, semantically dissimilar nouns, semantically dissimilar verbs) and the calculated results: semantically similar lists, semantically dissimilar lists, creativity, difference between semantically similar lists and semantically dissimilar lists



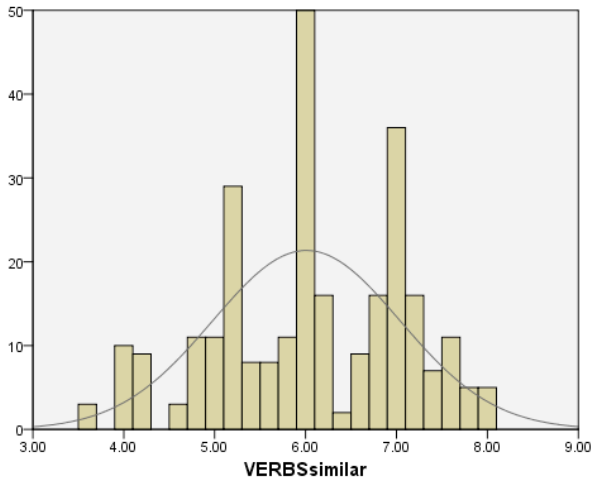
Graph 1. Distribution of participants' scores on RAT



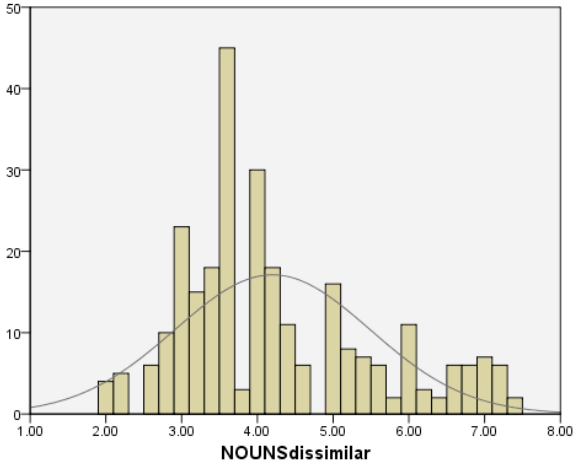
Graph 2. Distribution of participants' scores on difference between semantically similar lists and semantically dissimilar lists



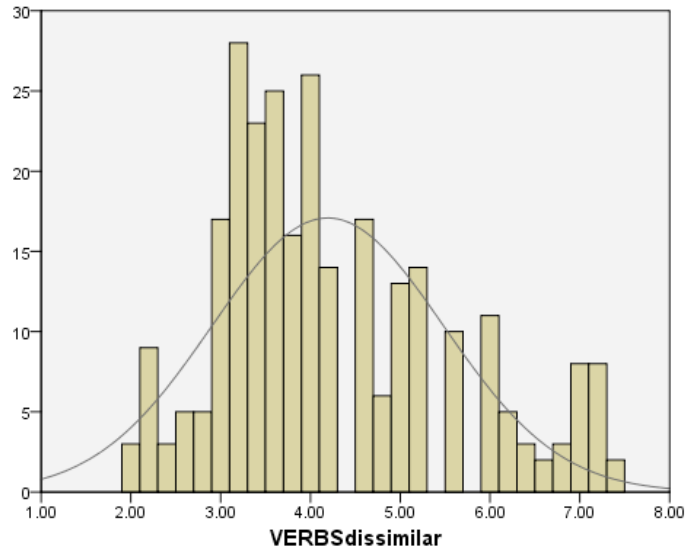
Graph 3. Distribution of participants' scores on semantically similar nouns



Graph 4. Distribution of participants' scores on semantically similar verbs



Graph 5. Distribution of participants' scores on semantically dissimilar nouns



Graph 6. Distribution of participants' scores on semantically dissimilar verbs

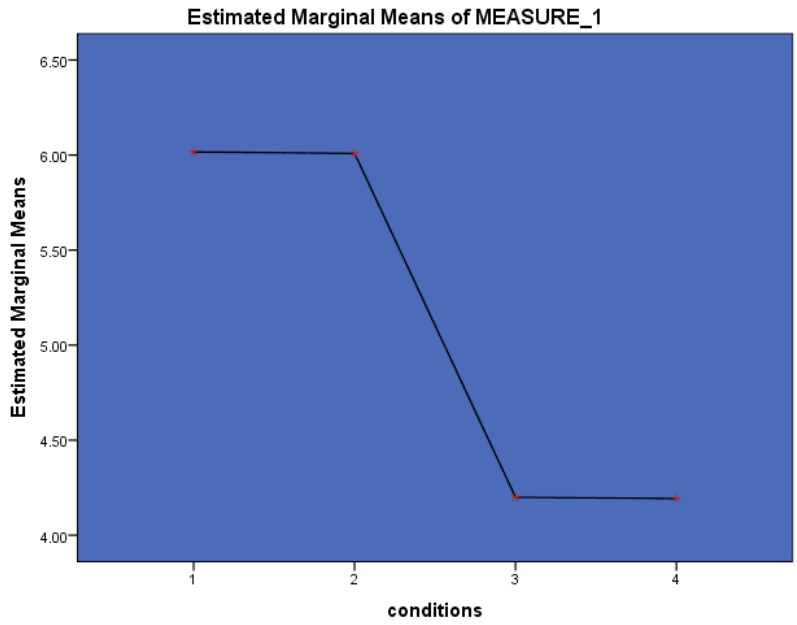
6.4 ANOVA on the immediate free recall task with within subjects factors

A statistical analysis on the immediate free recall task was carried out in order to investigate any effect of the independent variables on the dependent variable. The independent variables were three. The first variable was the semantic similarity within the items of the each list (semantically similar items versus semantically dissimilar items). The second variable was the grammatical category of the items of each list (nouns versus verbs). Finally, the last independent variable was the gender of the participants (male versus female). Therefore, each participant was assessed in four conditions. In Table 9 the descriptive statistics are presented for all of the participants' performances in the four conditions in the immediate free recall task with the dependent variable the number of correctly recalled items. Analytically, the four conditions are:

semantically similar nouns, semantically similar verbs, semantically dissimilar nouns and semantically dissimilar verbs. The descriptive statistics are also presented in Graph 7.

	Gender	Mean	Std. Deviation	N
Semantically similar nouns	Male	5.9457	1.08037	129
	Female	6.0782	1.04936	147
	Total	6.0163	1.06409	276
Semantically similar verbs	Male	5.9550	1.01666	129
	Female	6.0558	1.04542	147
	Total	6.0087	1.03143	276
Semantically dissimilar nouns	Male	4.1403	1.25776	129
	Female	4.2517	1.31510	147
	Total	4.1996	1.28749	276
Semantically dissimilar verbs	Male	4.1194	1.26886	129
	Female	4.2571	1.30725	147
	Total	4.1928	1.28895	276

Table 9. The descriptive statistics are presented for all of the participants' performance in the four conditions in the immediate free recall task.



Graph 7. Mean performance for all of the participants in the four conditions in the immediate free recall task

As stated in the section on method above, the experiment was a (3X3X2) factorial three way mixed analysis of variances. The number of correctly recalled items from the presented lists in the immediate free recall task was analysed with a split-plot ANOVA. Therefore, in each condition the maximum mark that could be obtained was 8 and the

minimum was 0. The participants' gender was the between participants factor, and had two levels, (1) female and (2) male. The type of information provided with regard to semantic similarity was the first within subjects factor. This factor had two levels: (1) semantically similar words and (2) semantically dissimilar words. The second within subjects factor was the grammatical category of the presented words and it had two levels: (1) nouns and (2) verbs. The results of the split-plot ANOVA are presented in Table 10 and 11 for the within subjects factors and in Table 12 for the between subjects factor.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Similarity	Sphericity Assumed	906.900	1	906.900	591.556	.000
	Greenhouse- Geisser	906.900	1.000	906.900	591.556	.000
	Huynh- Feldt	906.900	1.000	906.900	591.556	.000
	Lower-bound	906.900	1.000	906.900	591.556	.000
Similarity * gender	Sphericity Assumed	.004	1	.004	.003	.958
	Greenhouse- Geisser	.004	1.000	.004	.003	.958
	Huynh- Feldt	.004	1.000	.004	.003	.958
	Lower-bound	.004	1.000	.004	.003	.958
Error(Similarity)	Sphericity Assumed	420.062	274	1.533		
	Greenhouse- Geisser	420.062	274.000	1.533		
	Huynh- Feldt	420.062	274.000	1.533		
	Lower-bound	420.062	274.000	1.533		
Grammatical Category	Sphericity Assumed	.014	1	.014	.145	.703
	Greenhouse- Geisser	.014	1.000	.014	.145	.703
	Huynh- Feldt	.014	1.000	.014	.145	.703
	Lower-bound	.014	1.000	.014	.145	.703
Grammatical Category * gender	Sphericity Assumed	.000	1	.000	.005	.943
	Greenhouse- Geisser	.000	1.000	.000	.005	.943
	Huynh- Feldt	.000	1.000	.000	.005	.943
	Lower-bound	.000	1.000	.000	.005	.943
Error (Grammatical Category)	Sphericity Assumed	26.535	274	.097		
	Greenhouse- Geisser	26.535	274.000	.097		
	Huynh- Feldt	26.535	274.000	.097		
	Lower-bound	26.535	274.000	.097		
Similarity * Grammatical Category	Sphericity Assumed	9.417E-5	1	9.417E-5	.006	.936
	Greenhouse- Geisser	9.417E-5	1.000	9.417E-5	.006	.936
	Huynh- Feldt	9.417E-5	1.000	9.417E-5	.006	.936
	Lower-bound	9.417E-5	1.000	9.417E-5	.006	.936
Similarity * Grammatical Category * gender	Sphericity Assumed	.058	1	.058	3.953	.058
	Greenhouse- Geisser	.058	1.000	.058	3.953	.058
	Huynh- Feldt	.058	1.000	.058	3.953	.058
	Lower-bound	.058	1.000	.058	3.953	.058
Error (Similarity* Grammatical Category)	Sphericity Assumed	4.022	274	.015		
	Greenhouse- Geisser	4.022	274.000	.015		
	Huynh- Feldt	4.022	274.000	.015		
	Lower-bound	4.022	274.000	.015		

Table 10. Results of the split-plot ANOVA for the within subjects factors

Source		Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Similarity	Sphericity Assumed	.683	591.556	1.000
	Greenhouse- Geisser	.683	591.556	1.000
	Huynh-Feldt	.683	591.556	1.000
	Lower-bound	.683	591.556	1.000
Similarity * gender	Sphericity Assumed	.000	.003	.050
	Greenhouse- Geisser	.000	.003	.050
	Huynh- Feldt	.000	.003	.050
	Lower-bound	.000	.003	.050
Error (Similarity)	Sphericity Assumed			
	Greenhouse- Geisser			
	Huynh- Feldt			
	Lower-bound			
Grammatical Category	Sphericity Assumed	.001	.145	.067
	Greenhouse- Geisser	.001	.145	.067
	Huynh- Feldt	.001	.145	.067
	Lower-bound	.001	.145	.067
Grammatical Category * gender	Sphericity Assumed	.000	.005	.051
	Greenhouse- Geisser	.000	.005	.051
	Huynh- Feldt	.000	.005	.051
	Lower-bound	.000	.005	.051
Error (Grammatical Category)	Sphericity Assumed			
	Greenhouse- Geisser			
	Huynh- Feldt			
	Lower-bound			
Similarity * Grammatical Category	Sphericity Assumed	.000	.006	.051
	Greenhouse- Geisser	.000	.006	.051
	Huynh- Feldt	.000	.006	.051
	Lower-bound	.000	.006	.051
Similarity * Grammatical Category * gender	Sphericity Assumed	.014	3.953	.509
	Greenhouse- Geisser	.014	3.953	.509
	Huynh- Feldt	.014	3.953	.509
	Lower-bound	.014	3.953	.509
Error (Similarity* Grammatical Category)	Sphericity Assumed			
	Greenhouse- Geisser			
	Huynh- Feldt			
	Lower-bound			

Table 11. Results of the split-plot ANOVA for the within subjects factors

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	28597.563	1	28597.563	7378.334	.000	.964
Gender	3.997	1	3.997	1.031	.311	.004
Error	1061.992	274	3.876			

Table 12. Results of the split-plot ANOVA for the between subjects factor

The split-plot ANOVA analysis revealed for the between participants comparison that there was no significant main effect of the factor of participants' gender, F-value (1 – 274) of 1.031 ($p = 0.311$), indicating that the participants' performance in correctly recalling the presented items in the immediate free recall task was not affected by variation of gender. In other words, there was no significant difference between females and males performance in correctly recalling the presented items in the immediate free recall task.

The split-plot ANOVA analysis revealed for the within participants comparisons that the main effect due to the semantic similarity of the items was unlikely to have arisen by sampling error, assuming the null hypothesis to be true. Assumptions of normality, homogeneity of variance and sphericity were met. In particular, the analysis for the main effect of the semantic similarity of the items revealed an F-value (1 – 274) of 591.556 ($p < 0.001$) and represented a significantly large effect size (partial Eta squared) of.683, showing that nearly 68% of the variation in the number of correctly recalled items in the immediate free recall task can be accounted for by differing the semantic similarity of the presented items. The confidence interval showed that the population mean for the level of semantically similar items was 6.0199 and was likely (95%) to be found between 5.886 and 6.132. For the level of semantically dissimilar items the mean was 4.2047 and was likely (95%) to be found between 4.040 and 4.344. In Table 13 the descriptive statistics are presented for all of the participants' performance according to the factor of semantic similarity. These means are also presented in Graph 8. In Table 14 pairwise comparisons are presented for all of the participants' performance according to the factor of semantic similarity. In Table 15 multivariate tests are presented for all of the participants' performance according to the factor of semantic similarity.

Semantic Similarity	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Semantically similar lists	6.0199	.062	5.886	6.132
Semantically dissimilar lists	4.2047	.077	4.040	4.344

Table 13. Descriptive statistics for all of the participants' performance according to the factor of semantic similarity in immediate free recall task

(I) Similarity	(J) Similarity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Semantically similar lists	Semantically dissimilar lists	1.817*	.075	.000	1.670	1.964
Semantically dissimilar lists	Semantically similar lists	–1.817*	.075	.000	–1.964	–1.670

Based on estimated marginal means

*. The mean difference is significant at the.05 level.

b. Adjustment for multiple comparisons: Bonferroni

Table 14. Pairwise comparisons for all of the participants' performance according to the factor of semantic similarity in immediate free recall task

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.683	591.556[a]	1.000	274.000	.000	.683
Wilks' lambda	.317	591.556[a]	1.000	274.000	.000	.683
Hotelling's trace	2.159	591.556[a]	1.000	274.000	.000	.683
Roy's largest root	2.159	591.556[a]	1.000	274.000	.000	.683

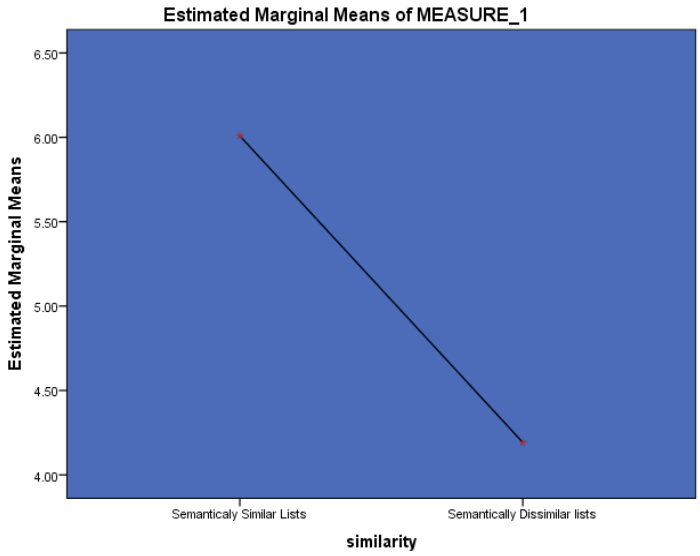
	Noncent. Parameter	Observed Power[b]
Pillai's trace	591.556	1.000
Wilks' lambda	591.556	1.000
Hotelling's trace	591.556	1.000
Roy's largest root	591.556	1.000

Each F tests the multivariate effect of Similarity. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

b. Computed using alpha =.05

Table 15. Multivariate tests for all of the participants' performance according to the factor of semantic similarity in immediate free recall task



Graph 8. Mean performance for all of the participants according to the factor of semantic similarity in immediate free recall task

The split-plot ANOVA analysis revealed that there was no significant main effect of the factor of grammatical category, F-value (1 – 274) of.145 (p = 0.703), indicating that the participants' performance in correctly recalling the presented items in the immediate free recall task was not affected by variation of the grammatical category of the provided items. In other words, there was no significant difference in participants' performance in correctly recalling the presented items in the immediate free recall task when they processed nouns or verbs.

The interaction between the three factors (the semantic similarity of the items, the grammatical category of the provided items and the participants' gender) was not significant F-value (1 – 274) of 3.953 (p = 0.058), indicating that the effect of the semantic similarity in the condition of nouns was similar in both males and females. By analogy, the effect of the semantic similarity in the condition of verbs was similar in both males and females. Furthermore, the absence of difference between males and females was observed in conditions of semantically similar nouns, semantically similar verbs, semantically dissimilar nouns and semantically dissimilar verbs. Finally, the absence of difference between lists of nouns and verbs in semantically similar items was true for both males and females and by analogy the absence of difference between lists of verbs and verbs in semantically similar items was true for both males and females.

The interaction between the factors of semantic similarity of the items and the grammatical category of the provided items was also not significant, F-value (1 – 274)

of.006 (p = 0.936), indicating that the factor of semantic similarity of the items behaves the same way at both levels of grammatical category. Likewise, the absence of difference between nouns and verbs is observed in both semantically similar items and dissimilar items. This analysis allows for the conclusion that the semantically similar items are more easily recalled than the semantically dissimilar regardless of whether the items are nouns or verbs.

The split-plot ANOVA analysis revealed that the interaction between the levels of participants' gender and the grammatical category was not significant, F-value (1 – 274) of.005 (p = 0.943), indicating that the absence differences between males and females was observed in the condition of nouns and verbs. Both females and males recalled the same number of nous and verbs.

Finally, the split-plot ANOVA analysis revealed that the interaction between the levels of participants' gender and the semantic similarity was not significant, F-value (1 – 274) of.003 (p = 0.958), indicating that the observed differences between the semantically similar and dissimilar items were the same for females and males. By analogy, females and males recalled the same number of semantically similar items and this observation was confirmed for the semantically dissimilar items.

6.5 Testing the main hypothesis of the study

The main hypothesis of the study, that creative individuals employ creative strategies during working memory processing, was tested using three separate methods in the analysis of the collected data. Two of the methods tested the hypothesis directly and the third tested it indirectly. The first involved the calculation of a bivariate correlation test, Pearson's r, while the second referred to the statistical method of Partial Correlation – Pearson's r. The third was again a bivariate correlation test, Pearson's r.

6.5.1 Rationale behind the methods

6.5.1.1 First method

The first method required the calculation of the difference between the participants' performance in two conditions of immediate free recall task. The mean difference between performances in lists containing semantically similar items and lists containing semantically dissimilar items was calculated for each participant. As predicted by relevant literature (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005) and confirmed in this study, there was an advantage found in the lists containing semantically similar items. The calculation of this difference

reflected to what extent the participants used different strategies in different working memory tasks. In other words, in order to recall lists containing semantically similar items the participants used an automatic strategy based on crystalised semantic relations between the items (the semantic properties of the items have significant impact on the recall strategy). However, this technique could not automatically be applied to lists containing semantically dissimilar items. In this case there were two options available. The first was to recall the items on the basis of phonological loop procedures (the semantic properties of the items do not have significant impact on the recall strategy) (Baddeley, 2012). The other option was the exploration of possible subjective semantic similarities between the items in order to use them as a recall strategy similar to that seen in the case of lists containing semantically similar items.

Thus, the advantage of a recall strategy based on the semantic similarity of the items could be observed in terms of both lists (semantically similar items and semantically dissimilar items) although it was observed mainly in the case of the lists containing semantically similar items. By calculating the difference in performance between the two aforementioned types, two tendencies were observed. Firstly, the difference could be large, indicating that there were no attempts to elaborate recall strategies based on the semantic properties of the items (for example, mean of performance on lists containing semantically similar items — 6/8 — versus the mean of performance on lists containing semantically dissimilar items — 3/6 — the difference is 3). Secondly, the difference could be small, reflecting that there were attempts to use recall strategies based on the semantic properties of the items (for example, the mean of performance on lists containing semantically similar items — 6/8 — versus the mean of performance on lists containing semantically dissimilar items — 4.5/6 — the difference is 1.5). In order to test the main hypothesis of this study it was necessary to calculate the degree of correlation between the aforementioned difference and the participants' score in terms of the creativity test (RAT). Therefore, a bivariate correlation test, Pearson's r, was performed (Dancey & Reidy, 2002). A negative correlation (low difference and high RAT score) would reveal that individuals employ semantic strategies underpinned by creative strategies during working memory processing.

6.5.1.2 Second method

The second method employed to test the main hypothesis refers to the statistical method of Partial Correlation – Pearson's r. The aim of this technique was to discover the association between the assessed creative abilities and working memory performance in

tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items). However, the relationship of those two dimensions had to be calculated without the effect of participants' performance in tasks which facilitated the employment of automatic/common recall strategies (condition of semantically similar items). In theory a calculation of the association between the assessed creative abilities and working memory performance in tasks requiring the employment of creative recall strategies could be obtained by using a sample of participants with the same performance in recalling items. However, this is impossible as recall performance in working memory processing is affected by multiple factors (Baddeley, 2012).

Thus, in order to remove the effect of participants' performance in tasks which facilitate the employment of automatic/common recall strategies a "partialling out" technique by statistical means was applied. This technique can also be described as "holding general participants' recalling performance constant". The rationale behind the technique is the correlation of assessed creative abilities and working memory performance in tasks requiring the employment of creative recall strategies while also removing the effects of general recall performance (r). This rationale is demonstrated in Figure 5. The correlation between creative abilities and working memory performance in tasks requiring the employment of creative recall strategies without partialling out the third variable is A + B.

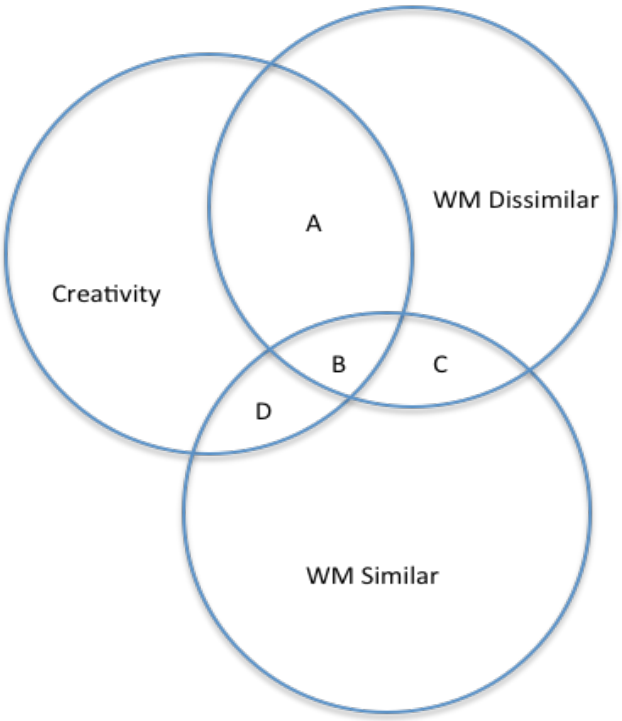


Figure 5. Representation in graphics the rationale of partialling out the effect of general participants' recalling performance on the correlation between creative abilities and the working memory performance in tasks requiring the employment of creative recall strategies

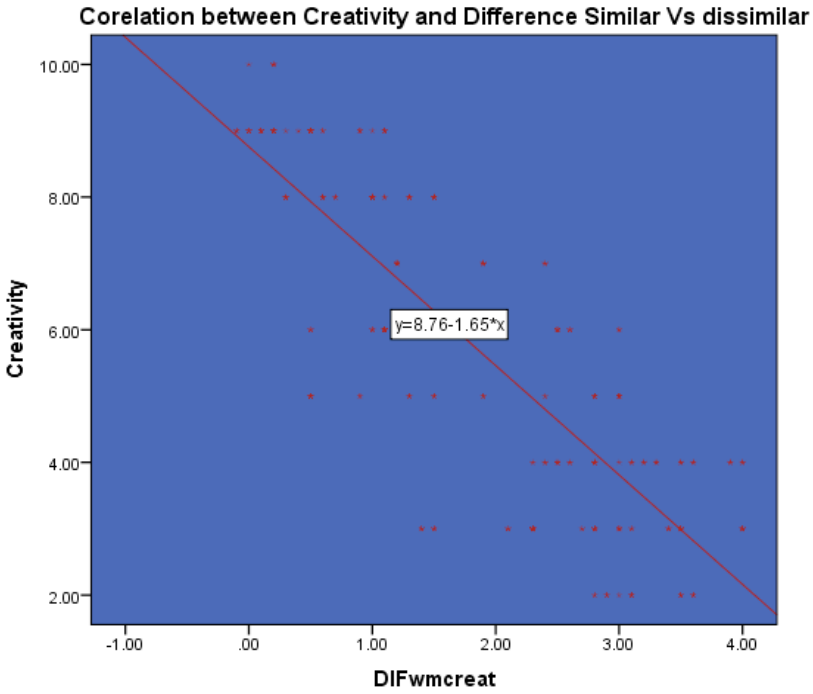
6.5.2 Bivariate correlation test, Pearson's Product Moment Correlation (Pearson's r)

For each participant the mean difference between performances in two conditions of the experiment were calculated; lists containing semantically similar items and lists containing semantically dissimilar items. Two obtained measurements were then used for the Pearson's Product Moment Correlation (Pearson's r), in order to test the hypothesis of this thesis. The analysis correlated the participants' score on the creativity test (RAT) and the difference between lists containing semantically similar items and those containing semantically dissimilar items. The range of the scores for the RAT ranged from 0 to 10. The range of the scores for the difference between lists containing semantically similar items and lists containing semantically dissimilar items ranged from 0 to 8. In Table 16 the descriptive statistics (number of participants, means and standard deviations) are presented for all the participants performance in the two measurements.

	Mean	Std. Deviation	N
Creativity	5.7536	2.33023	276
Difference between semantically similar and dissimilar lists	1.8225	1.16216	276

Table 16. Descriptive statistics (N number of participants, means, standard deviations) for all the participants' performance in the two measurements

Before carrying out the Pearson's r, minimum data requirements had to be met (Dancey & Reidy, 2002). Therefore, analytically, the following conditions were met. Both variables were necessarily continuous (that is, interval and ratio level). All cases had values on both variables. There was a linear relationship between the variables (revealed by the scatterplot of correlation between the variables). There was independence of observations indicating that there was no relationship between the values of variables between cases (the values for all variables across cases were unrelated for any case, the value for any variable did not influence the value of any variable for other cases, and no case influenced another case or any variable), each pair of variables was bivariately normally distributed, the sample of data from the population was random, and there were no outliers. Scattergram 1 presents the scatterplot of correlation between the variables and provides a good illustration of how the two exploratory variables (score on RAT and difference between lists containing semantically similar items and those containing semantically dissimilar items) are related, indicating that the variables have linear relationships.



Scattergram 1. Scatterplot of correlation between scores on RAT and difference between lists containing semantically similar items and lists containing semantically dissimilar items for all the participants' (N= 276; r = –.823)

The null hypothesis (H_0) and the alternative hypothesis (H_1) of the significance test for correlation can be expressed for a two-tailed significance test:

H_0: r = 0 ("the population correlation coefficient is 0; there is no association")

H_1: r ≠ 0 ("the population correlation coefficient is not 0; a non zero correlation could exist"). The results for the Pearson's r are presented in Table 17.

Correlations

		Creativity	Difference between semantically similar and dissimilar lists
Creativity	Pearson Correlation	1	–.823**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	1493.246	–612.972
	Covariance	5.430	–2.229
	N	276	276
Difference between semantically similar and dissimilar lists	Pearson Correlation	–.823**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	–612.972	371.421
	Covariance	–2.229	1.351
	N	276	276

**. Correlation is significant at the 0.01 level (2-tailed).

Table 17. Results for the Pearson's Product Moment Correlation (Pearson's r)

The hypothesis stating that the participants' score on RAT would be negatively related to the difference between scores of lists containing semantically similar items and lists containing semantically dissimilar items was confirmed. The two-tailed significance Pearson's r revealed an r = –.823 indicating a strong negative correlation coefficient between the scores. The associated probability level ($p < .001$) indicated that these results were unlikely to have arisen by sampling error, allowing the null hypothesis that there is no relationship between the two exploratory variables to be rejected. Based on the results, we can state the following:

- The score on the RAT and the difference between scores for lists containing semantically similar items and those containing semantically dissimilar items have a statistically significant linear relationship ($p < .001$).
- The direction of the relationship is negative, meaning that these variables do not tend to increase together (that is, a greater score on the creativity test is associated with a lower difference between the scores for the lists).

6.5.3 Partial Correlation – Pearson's r

As already discussed, the main hypothesis of the study was tested using different techniques, the second being a Partial Correlation – Pearson's r analysis. For the Partial

Correlation – Pearson's r analysis, three measurements were obtained. The analysis correlated the participants' score on the RAT and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items). However, the relationship between those two dimensions necessarily had to be calculated without the effect of participants' performance in tasks which facilitate the employment of automatic/common recall strategies (condition of semantically similar items).

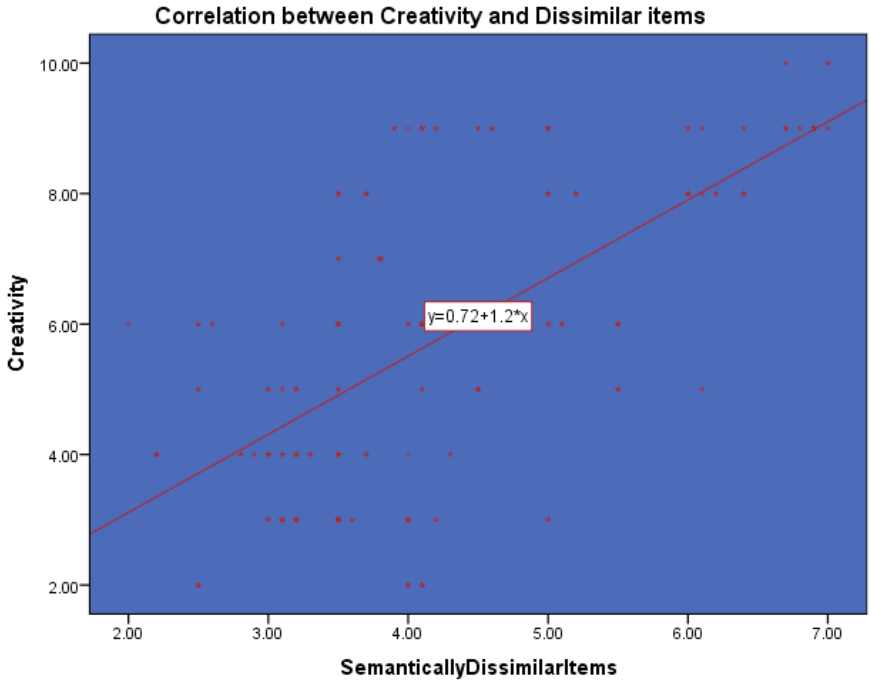
The range of the scores for the RAT ranged from 0 to 10. The range of scores for the condition of semantically dissimilar items ranged from 0 to 8. Finally, the range of the scores for the third variable, the condition of semantically similar items, which effect was partialled out, ranged from 0 to 10. In Table 18 the descriptive statistics (number of participants, means and standard deviations) are presented for all the participants performance in the three measurements.

	Mean	Std. Deviation	N
Creativity	5.7536	2.33023	276
Semantically dissimilar lists	4.2047	1.23578	276
Semantically similar lists	6.0199	.96306	276

Table 18. Descriptive statistics (N number of participants, means, standard deviations) for all the participants' performance in the three measurements

Before carrying out the Partial Correlation – Pearson's r analysis minimum data requirements and specific assumptions had to be met (Dancey & Reidy, 2002). Therefore, analytically, the following conditions were met. There was one dependent variable (working memory performance on the condition of semantically dissimilar lists) and one independent variable (score on the RAT) and these were measured on a continuous scale (that is, the number of correctly recalled items). There was one control variable, also known as covariates, used to adjust the relationship between the other two variables (that is, working memory performance on the condition of semantically similar lists). This control variable was also measured on a continuous scale (that is, number of correctly recalled items). There was a linear relationship between all three variables that was confirmed by the scatterplot of correlation between the variables. The sample of data from the population was random and there were no outliers. Finally, there was bivariate normality for each pair of variables tested by the Shapiro-Wilk test of normality.

Scattergram 2 presents the scatterplot of correlation between the variables and provides a good illustration of how the two exploratory variables (score on creativity test (RAT) and the working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items)) are related, indicating that the variables have linear relationships.



Scattergram 2. Scatterplot of correlation between scores on RAT and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items)

The null hypothesis (H_0) and the alternative hypothesis (H_1) of the significance test for correlation can be expressed for a two-tailed significance test:

H_0: r = 0 ("the population correlation coefficient is 0; there is no association")

H_1: r ≠ 0 ("the population correlation coefficient is not 0; a non zero correlation could exist"). The results for the Partial Correlation – Pearson's r are presented in Table 19.

Control Variables			Creativity	Semantically dissimilar lists
Semantically similar lists	Creativity	Correlation	1.000	.827
		Significance (2-tailed)	.	.000
		df	0	273
	Semantically dissimilar lists	Correlation	.827	1.000
		Significance (2-tailed)	.000	.
		df	273	0

**. Correlation is significant at the 0.01 level (2-tailed).

Table 19. Results for the Partial Correlation – Pearson's r

A Partial Correlation – Pearson's r analysis was run to determine the relationship between scores on the RAT and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items) while controlling for working memory performance on the condition of semantically similar lists. There was a strong, positive partial correlation between scores on the RAT (5.7536 ± 2.33023) and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items) (4.2047 ± 1.23578) while controlling for working memory performance on the condition of semantically similar lists (6.0199 ±.96306), r (273) =.827, N = 276. The associated probability level ($p < .001$) indicated that these results were unlikely to have arisen by sampling error, allowing the null hypothesis that there is no relationship between the two exploratory variables to be rejected. Furthermore, these results indicated that working memory performance on the condition of semantically similar lists had very little influence in controlling the relationship between scores on the RAT and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items). The direction of the relationship (that is, the score on the RAT and the scores on the condition of semantically dissimilar items are positively correlated), indicating that these variables tend to increase together (that is, a greater score on the creativity test is associated with greater scores on the condition of semantically dissimilar items). Furthermore, participants' general abilities in recalling items (condition of semantically similar lists) do not affect the relation between the tested variables.

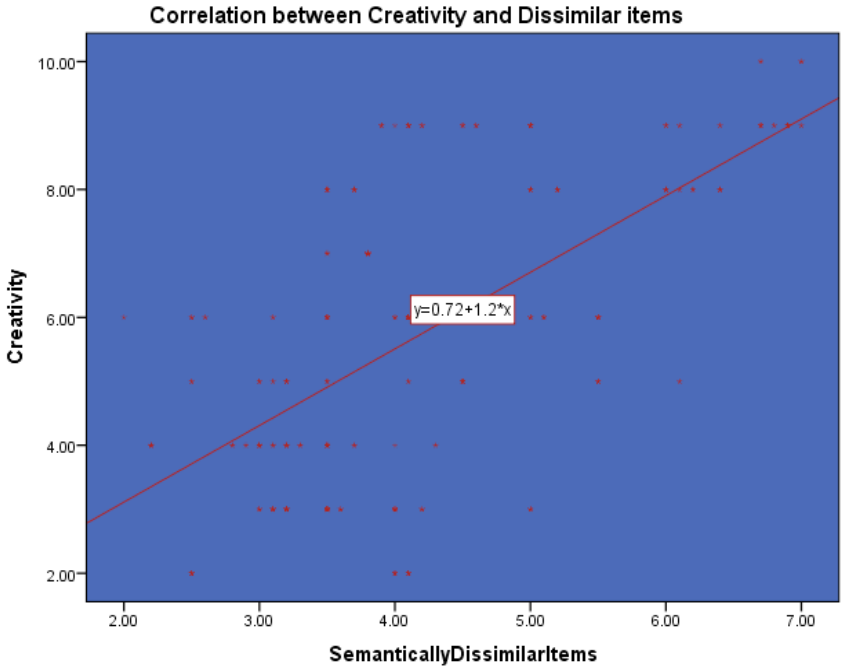
6.5.4 Comparison between Partial Correlation – Pearson's r analysis and Pearson's Product Moment Correlation (Pearson's r) for the same variables

The results of the Partial Correlation – Pearson's r analysis were then compared with an additional bivariate correlation test, Pearson's r, between scores on the RAT and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items). The scores for the RAT ranged from 0 to 10. The scores for working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items) ranged from 0 to 8. In Table 20 the descriptive statistics (number of participants, means and standard deviations) are presented for all the participants performance in the two measurements.

	Mean	Std. Deviation	N
Creativity	5.7536	2.33023	276
Semantically dissimilar lists	4.2047	1.23578	276

Table 20. Descriptive statistics (N number of participants, means, standard deviations) for all the participants' performance in the two measurements

Before carrying out the Pearson's r minimum data requirements had to be met (Dancey & Reidy, 2002). Therefore, analytically, the following conditions were met. Both variables were continuous (that is, interval and ratio level). All cases had values on both variables. There was a linear relationship between the variables (revealed by the scatterplot of correlation between the variables). There was independence of observations indicating that there was no relationship between the values of variables between cases (the values for all variables across cases were unrelated for any case, the value for any variable did not influence the value of any variable for other cases, and no case influenced another case in terms of any variable), each pair of variables was bivariately normally distributed, the sample of data from the population was random, and there were no outliers. Scattergram 3 presents the scatterplot of correlation between the variables and provides a good illustration of how the two exploratory variables are related, indicating that the variables have linear relationships.



Scattergram 3. Scatterplot of correlation between scores on the RAT and scores on lists containing semantically dissimilar items.

The null hypothesis (H_0) and the alternative hypothesis (H_1) of the significance test for correlation can be expressed for a two-tailed significance test:

H_0: r = 0 ("the population correlation coefficient is 0; there is no association")

H_1: r ≠ 0 ("the population correlation coefficient is not 0; a non zero correlation could exist"). The results for the Pearson's r are presented in Table 21.

		Creativity	Semantically dissimilar lists
Creativity	Pearson Correlation	1	.835**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	1493.246	503.020
	Covariance	5.430	1.829
	N	276	276
Semantically dissimilar lists	Pearson Correlation	.835**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	503.020	419.964
	Covariance	1.829	1.527
	N	276	276

**. Correlation is significant at the 0.01 level (2-tailed).

Table 21. Results for the Pearson's Product Moment Correlation (Pearson's r)

The hypothesis stating that the participants' score on the RAT would be positively correlated to the scores of lists containing semantically dissimilar items was confirmed. The two-tailed significance Pearson's r revealed an r =.835 indicating a strong positive correlation coefficient between the scores. The associated probability level ($p < .001$) indicated that these results were unlikely to have arisen by sampling error, allowing the null hypothesis that there is no relationship between the two exploratory variables to be rejected. Based on theses results, and the results of the Partial Correlation – Pearson's r analysis we can make the following interpretations.

The first order correlation revealed a strong positive correlation between the target variables an r =.835. However, in the second order correlation the r size was not significantly reduced r =.827 indicating that the general working memory recall abilities had very little influence in controlling the relationship between scores on the RAT and scores on lists containing semantically dissimilar items. These findings are in conjunction with the first method in terms of testing the main hypothesis of the study.

6.6 Testing hypotheses further to the main hypothesis of the study

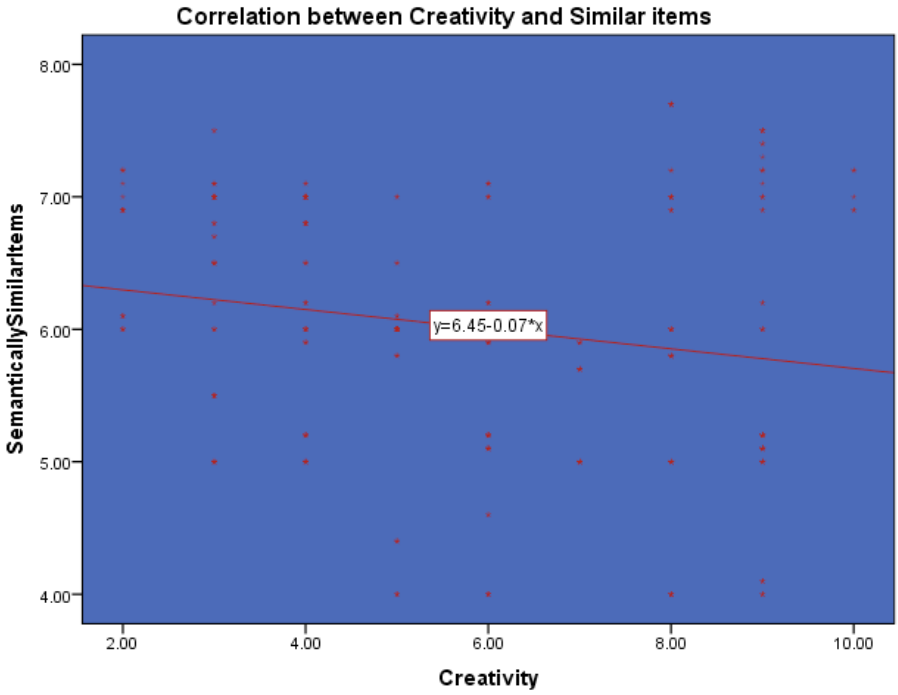
Further to the test of the main hypothesis, an additional analysis was performed in order to assess a possible correlation between the scores on the RAT and those on lists containing semantically similar items. This was done using the Pearson's r. According to the relevant literature it was expected and confirmed that there would be a very low, or perhaps even absence of, association (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). The scores for the RAT ranged from 0 to 10, while the scores for the working memory performance in tasks not requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically similar items) ranged from 0 to 8. In Table 22 the descriptive statistics (number of participants, means and standard deviations) are presented for all the participants performance in the two measurements.

	Mean	Std. Deviation	N
Creativity	5.7536	2.33023	276
Semantically similar lists	6.0199	.96306	276

Table 22. Descriptive statistics (N number of participants, means, standard deviations) for all the participants' performance in the two measurements

Before carrying out the Pearson's r minimum data requirements had to be met (Dancey & Reidy, 2002). Therefore, analytically, the following conditions were met. Both

variables were continuous (that is, interval and ratio level). All cases had values on both variables. There was a linear relationship between the variables (revealed by the scatterplot of correlation between the variables). There was independence of observations indicating that there was no relationship between the values of variables between cases (the values for all variables across cases were unrelated for any case, the value for any variable did not influence the value of any variable for other cases, and no case influenced another case on any variable), each pair of variables was bivariately normally distributed, the sample of data from the population was random, and there were no outliers. Scattergram 4 presents the scatterplot of correlation between the variables and provides a good illustration of how the two exploratory variables are not efficiently related although the variables have linear relationships.



Scattergram 4. Scatterplot of correlation between scores on the RAT and scores on lists containing semantically similar items.

The null hypothesis (H_0) and the alternative hypothesis (H_1) of the significance test for correlation can be expressed for a two-tailed significance test:

H_0: r = 0 ("the population correlation coefficient is 0; there is no association")

H_1: r ≠ 0 ("the population correlation coefficient is not 0; a non zero correlation could exist"). The results for the Pearson's r are presented in Table 23.

		Creativity	WMsimilar
Creativity	Pearson Correlation	1	–.179**
	Sig. (2-tailed)		.003
	Sum of Squares and Cross-products	1493.246	–110.445
	Covariance	5.430	–.402
	N	276	276
Semantically similar lists	Pearson Correlation	–.179**	1
	Sig. (2-tailed)	.003	
	Sum of Squares and Cross-products	–110.445	255.060
	Covariance	–.402	.927
	N	276	276

**. Correlation is significant at the 0.01 level (2-tailed).

Table 23. Results for the Pearson's Product Moment Correlation (Pearson's r)

The two-tailed significance Pearson's r revealed an r = –.179 indicating a very weak negative correlation coefficient between the scores. The associated probability level ($p < .05$) indicated that these results were unlikely to have arisen by sampling error, allowing the null hypothesis that there is no relationship between the two exploratory variables to be rejected. Based on these results we can make the following interpretations:

- The score on the RAT and scores of lists containing semantically similar items have a statistically significant linear relationship ($p < .05$).

The direction of the relationship is negative, meaning that these variables do not tend to increase together (that is, a greater score on the creativity test is associated with lower scores in lists containing semantically similar items). Thus, considering the very weak negative correlation coefficient we could assume that the main hypothesis of the study, that creative individuals tend to apply creative strategies mainly on working memory tasks when no obvious automatic strategy could be applied, is correct. Furthermore the negative correlation indicates that creative individuals have a relative disadvantage in recall tasks that facilitate automatic strategies, as they tend to partially implement creative strategies due to their inability to inhibit the flow of irrelevant information. The employment of creative strategies thus comes at a cost. In contrast, non creative individuals avoid this cost by implementing automatic strategies.

7. Discussion

7.1 Rationale behind the experiment and summary of the findings

7.1.1 Rationale

The rationale behind the present experiment is based on the hypothesis that working memory is a limited capacity system and that the applied strategies in free recall tasks are determined by the individual differences and specific requirements of the referent task (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012). Research on the retrieval of verbal items supports the distinction between a fast, automatic activation of mainly phonological or partially semantic representations and a slower, more controlled, and strenuous mechanism of deep semantic strategic retrieval (Whitney, Grossman & Kircher, 2009; Gold et al., 2006; Badre & Wagner, 2002). Research into working memory and more specifically in terms of item recall has shown that semantic factors have a significant positive effect (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Items, specifically words, are more easily and successfully recalled when they are all drawn from the same semantic category (Baddeley, 2007). Therefore, in groups of semantically related words the effect of an automatic phonological strategy is likely to be reduced or abandoned in favour of a crystalised semantic strategic retrieval as the relationship between the items has already been learned and applied. In contrast, an absence of contextual semantic support characterises standard working memory tasks involving the presentation of lists of unrelated words (Saint-Aubin, Ouellette & Poirier, 2005). For most of the population, in terms of groups of semantically unrelated words the most obvious and generally adopted strategy is reliance on phonological encoding (Baddeley, 2000).

However, there are contradictions over the question of which type of strategy (phonological, automatic or controlled semantic) is applied in specific tasks as well as their gravity effect. Some studies have demonstrated that switching between phonological and semantic encoding and recall is possible and observable (Campoy & Baddeley, 2008; Gilhooly, Fioratou, Anthony & Wynn, 2007; Hanley & Bakopoulou, 2003). Therefore, the elaboration of a more controlled and strenuous mechanism of semantic strategic retrieval is not totally abandoned in favour of the automatic phonological strategy (Larigauderie, Michaud & Vicente, 2011). According to the individual's ability to apply problem solving strategies effectively, different strategies (phonological, automatic or controlled semantic) can be used (Conway, Cowan,

Bunting, Therriault & Minkoff, 2002). Thus, individual differences can play a significant role in the selection of the most effective strategy. It is reasonable to presume that this distinction can also be applied to working memory and thus that the strategies that underpin creative behaviour also have a significant effect on working memory encoding and recall processes. This assumption of a relationship between creativity and working memory leads to the question of which strategies are employed and how these creative strategies are used in working memory processes.

Some studies have indirectly investigated the relationship between working memory and creativity (Tse, Li & Altarriba, 2011). The majority of these hypothesise that working memory capacity is a prerequisite for creativity generally and, more specifically, for cognitive flexibility, abstract thinking, strategic planning and processing speed in long-term memory (Rastogi & Sharma, 2010; Deitrich, 2004). In this case, a working memory buffer is required for creative thinking and, by analogy, operation and storage of working memory affects creative problem solving. Individuals with high working memory capacity are more likely to be successful at overcoming interference caused by automatic, unoriginal responses and also be more successful at using strategies to generate novel approaches and responses for creative thinking tasks (Baddeley, 2007). In other words working memory benefits creativity for it enables the individual to maintain attention to the task and prevents undesirable mind wandering (De Dreu, Nijstad, Baas, Wolsink & Roskes, 2012). However, the main disadvantage of these studies is that the majority of them do not use working memory tasks requiring creative abilities or solutions (Yeh, Lai, Lin, Lin & Sun, 2015). Also, there is no research investigating how creativity and creative strategies can affect the strategies incorporated in working memory processes.

Although there is no research investigating how creativity and creative strategies can affect the strategies incorporated in working memory processes, in this area to date, we can make some assumptions on the basis of relevant research. For example, selective attention, which involves the ability to focus cognitive resources on information relevant to goals, has been found to influence working memory performance (Gazzaley & Nobre, 2012). By analogy, both modality dependent working memory mechanisms and modality independent attention control mechanisms can therefore exercise some influence over insight problem solving (Chein & Weisberg, 2013). Furthermore, Lee and Therriault (2013) link working memory prerformance with

the underlying cognitive mechanisms of divergent, convergent thinking as well as associative processing, albeit indirectly.

Benedek, Konen and Neubauer's (2012) study also suggests a relationship between creativity and working memory. Their analysis reveals that both updating and inhibition significantly predict divergent thinking and overall creative task performance. According to the concept of creativity based on the activation and retrieval of ideas that are only remotely associated with the problem or stimulus, they point out the importance of inhibition. Effective working memory abilities are supported by effective inhibition of salient, strongly related concepts (Gupta, Jang, Mednick & Huber, 2012; Gupta, 2009). Inhibition represents the capacity to reduce interference by semantically related representations and thus facilitates the activation of semantically remote concepts. Furthermore, significant updating ability or working memory capacity enables the supervised search and manipulation of a larger number of representations. This enables individuals to retrieve semantic concepts relevant to the problematic situation, which is a requirement for the generation of creative ideas.

However, Benedek, Konen and Neubauer explain working memory contribution, they leave unexplained the parameters for choosing this creative strategy. In other words they do not explain what determines the relevant semantic concepts at working memory level. This question is investigated in the present thesis and results indicate that creativity and working memory are in a constant dynamic relationship. The importance of the target task, which was taken into consideration in experiments relted to this thesis, was noted the authors as a major limitation of their study:

> A few limitations of the present study should be acknowledged. First of all, this study used latent variables of executive functions, which were each defined by three task blocks of a relevant executive task, but not by different tasks of the same construct (p. 80).

As demonstrated throughout this thesis, there are significant gaps in the literature in terms of examining how creativity and creative strategies are related to the strategies incorporated in working memory processes. The main objective of this thesis is to answer some of these unanswered questions (listed below), using the methodology of applying working memory tasks requiring creative abilities or solutions, combined with analyses of typical assessments of creativity assessments and verbal working memory tasks.

The reviewed literature reveals the need to find answers for specific questions in terms of the relationship between working memory and creativity:

- What are the characteristics of the relationship between working memory and creativity?
- Is the relationship between working memory and creativity task dependent? Research on working memory indicates that working memory performance depends on the characteristics of the task and the employed strategies.
- Are creative strategies elaborated in working memory processes?
- Do creative individuals employ specific creative strategies during specific working memory tasks?

These questions along with the theoretical and empirical evidence of the relevant literature (previously reviewed) scaffold the main hypothesis of the present study:

- Creative individuals are able to employ different and controlled strategies in working memory processing according to the special characteristics of the referent task.

7.1.2 Experimental design and summary of the results

The experiment related to this study included data collection of participants' demographic information, performance of the RAT – Greek, and working memory performance demonstrated by two different immediate free recall tasks (the first task contained lists of semantically similar words and the second task contained lists of semantically dissimilar words). In addition, the difference between the participants' performance in the two immediate free recall tasks was calculated. The implementation of two different recall tasks allowed for the observation of performance in tasks requiring different strategies.

Analysis of the collected data is divided into two sections. The first concentrates on the main hypothesis of the study, that creative individuals employ creative strategies during specific working memory processing. This hypothesis was tested using three separate methods. Two tested the hypothesis directly while the third tested the hypothesis indirectly. The second section aims to investigate two general tendencies observed in the literature. The first tendency is the performance difference between lists containing semantically similar items and those containing semantically dissimilar items. The second tendency is the correlation between working memory performance in lists containing semantically similar items and creativity performance. Data from a large number of participants was used for all the analyses listed above.

The sample group is representative of Greek monolingual adults studying or having studied in a Greek university. Data was collected from a total of 276 participants. The sample consisted of 129 males and 147 females. The size of the sample was considered sufficient for the applied statistical analyses (Dancey & Reidy, 2002; Anastasi & Urbina, 1997; Kaiser, 1994). The average age of the sample was 25.33 years (SD = 2.1). According to the academic qualifications of the participants they were allocated into seven groups. The seven groups included the following categories: secondary education, tertiary education student, tertiary education (for example, BSc, BA) graduate, postgraduate student, postgraduate title, PhD and other.

Before the administration of the main tasks a pilot study was performed using a sample of 25 participants. As the survey was conducted in Greece under the supervision of an Australian university (Macquarie University) regulations and guidelines from both countries were taken into consideration. Before any data could be collected from the participants, the present research had to first comply with the National Health and Medical Research Council (NHMRC)'s Australian Code for the responsible Conduct of Research[1] (2007), the National Statement on ethical conduct in Human Research.[2] The study also had to comply with the relevant legislation and guidelines of Hellenic Society for Ethics, the Hellenic General Office of Research and Technology, and the relevant universities.

Finally, the validity of the immediate free recall task was ensured by performing a construct validity procedure. The construct validity was assessed using a Principal Component Analysis and a Confirmatory Factor Analysis. Both analyses revealed two factors: semantically similar items and semantically dissimilar items according to the relevant literature (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012; Tse, Li & Altarriba, 2011) and the design of the tasks.

7.1.2.1 First section — testing the main hypothesis

The rationale behind the three methods used in the analysis to test the main hypothesis, with their results in summary, are presented below.

For the first method a bivariate correlation test, Pearson's r, was carried out. The degree of correlation between the difference in participants' performance in the two immediate free recall tasks and the participants' score on the creativity test (RAT) was calculated. The two-tailed significance Pearson's r revealed an r = –.823 indicating a

[1] www.nhmrc.gov.au/guidelines-publications/r39.
[2] www.nhmrc.gov.au/guidelines-publications/e72.

strong negative correlation coefficient between the participants' score on the RAT and the difference between scores for lists containing semantically similar items and lists containing semantically dissimilar items. The associative probability was significant at $p < .001$. These findings indicate that the variables do not tend to increase together (that is, a greater score on the creativity test is associated with lower difference between the scores for the two immediate recall tasks).

For the second method a Partial Correlation – Pearson's r was carried out. Three measurements were used. The analysis correlated the participants' score on the RAT and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items). The relationship between those two dimensions was calculated without the effect of participants' performance in tasks which facilitate the employment of automatic/common recall strategies (condition of semantically similar items). The analysis revealed a strong positive partial correlation $r(273) = .827$ between scores on the creativity test and working memory performance in the condition of semantically dissimilar items. The associative probability was significant at $p < .001$. The effect of the condition of semantically similar items was taken out, revealing only the targeted correlation. Thus, it was revealed that the main variables tend to increase together (that is, a greater score on the creativity test is associated with greater scores on the condition of semantically dissimilar items).

Finally, the third method was a bivariate correlation test, Pearson's r. The correlation between scores on the RAT and working memory performance in tasks requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically dissimilar items) was calculated. This analysis was carried out for two reasons, firstly in order to test the hypothesised correlation itself and secondly to compare the first and the second order correlations. The first order was the Partial Correlation – Pearson's r between the score on the RAT and working memory performance in tasks not requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically similar items). The second order was the Pearson's r between the scores on the RAT and working memory performance in tasks not requiring the employment of creative recall strategies in order to achieve efficient performance (condition of semantically similar items). The comparison between the first and the second order correlations revealed that the effect of the crystalised recall strategies (condition of semantically similar items) was not

significant. The first order correlation revealed a strong positive correlation between the target variables, an r = .835. However, in the second order correlation the r size was not significantly reduced r = .827 indicating that the crystalised recall strategies had very little influence in controlling the relationship between the scores on the RAT and the scores on lists containing semantically dissimilar items. These findings are in conjunction with the first method in testing the main hypothesis of the study.

7.1.2.2 Second section — investigation of two general tendencies observed in the literature

The second section of the analysis aimed to investigate general tendencies observed in the literature. In particular, the difference in performance between lists containing semantically similar items and lists containing semantically dissimilar items was tested using an ANOVA. The second section of the analysis tested the correlation between working memory performance on lists containing semantically similar items and creativity performance using a bivariate correlation test, Pearson's r.

The ANOVA was based on reported findings in the literature indicating that items and specifically words are better recalled when they are all drawn from the same semantic category (Baddeley, 2007). For the present experiment a comparison was made between the condition of semantically similar items and semantically dissimilar items. Furthermore, the analysis compared the differences observed between females and males during the experiment as well as the differences observed between the conditions of verbs and nouns.

The analysis revealed a significant main effect of the factor of semantic similarity F-value (1 – 274) of .145 (p = 0.001) representing a significantly large effect size (partial Eta squared) of .683, demonstrating that nearly 68% of the variation in the number of correctly recalled items in the immediate free recall task can be accounted for by differing the semantic similarity of the presented items. Thus, as expected according to the literature (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005) participants correctly recalled more items from the condition of semantically similar items than from the condition of semantically dissimilar items.

There was no significant main effect for the variable of gender F-value (1 – 274) of 1.031 (p = 0.311), indicating that the participants' performance in correctly recalling the presented items in the immediate free recall task was not affected by variation of the participants' gender. In other words, there was no significant difference between female

and male performance in correctly recalling the presented items in the immediate free recall task.

Furthermore, the split-plot ANOVA analysis revealed that there was not a significant main effect of the factor of grammatical category, F-value (1 – 274) of .145 ($p = 0.703$), indicating that the participants' performance in correctly recalling the presented items in the immediate free recall tasks was not affected by variation of the grammatical category of the provided items. In other words, there was no significant difference in participants' performance in correctly recalling the presented items in the immediate free recall tasks when they processed nouns or verbs.

Finally, all the possible interactions between the variables were tested. No significant interaction at any level was observed. In particular, the following interactions were non significant: interaction between the three factors (the semantic similarity of the items, the grammatical category of the provided items and the participants' gender), interaction between the factors of semantic similarity of the items and the grammatical category of the provided items, interaction between the levels of participants' gender and the grammatical category, and finally, interaction between the levels of participants' gender and the semantic similarity.

In regard to the second tendency, further to the testing of the main hypothesis, a bivariate correlation test, Pearson's r, was carried out. This sought to test the correlation between working memory performance on lists containing semantically similar items and creativity performance. This was considered essential for investigation of the semantic similarity phenomenon in relation to creativity and more importantly in order to allow comparisons with previous studies, revealing that in well known or simple tasks (less demanding) there is no observable or negative effect of creativity (Yeh, Lai, Lin, Lin & Sun, 2015; Takeuchi, et al., 2011; Tse, Li & Altarriba, 2011; Tse S. C., 2009). The correlation analysis of the present data revealed a very weak negative correlation coefficient $r = –.179$ between working memory performance on lists containing semantically similar items and creativity performance. The associated probability level ($p < .05$) indicated that these results were unlikely to have arisen by sampling error.

7.2 The relationship between working memory and creativity — the phenomenon of semantic similarity in immediate free recall

This section is divided into two sections according to the aims of the study and the statistical analyses performed. The first section addresses the main research hypothesis:

creative individuals are able to employ different and controlled strategies in working memory processing according to their creative abilities and the special characteristics of the referent task. The second section addresses the findings of the study related to the observed differences in working memory tasks between the conditions of semantically similar items and semantically dissimilar items. Further, in the second section general tendencies about the relationship between working memory capacity and creativity are discussed only in regard to the condition of semantically similar items.

7.2.1 Evidence of the influence of creative strategies in immediate free recall and semantic encoding

The main hypothesis of the study, that creative individuals employ creative strategies during specific working memory processing (dependency on the referent task), was tested using three separate methods in terms of analysis of the collected data. All three methods revealed similar results allowing valid interpretations. For the purpose of this section the three methods will be discussed individually and in conjunction. A general interpretation will then be attempted, homogenising the findings into a meaningful block and summarising the interpretations in order to allow a dynamic comparisson with previous research (i.e. Campoy, Castellà, Provencio, Hitch & Baddeley, 2015, Baddeley, 2012, Larigauderie, Michaud & Vicente, 2011). Overall, the results allowed for two assumptions. The first was that participants used different encoding and recall strategies according to the referent task. The second assumption was that the employment of specific strategies is highly affected by individual differences in regard to creativity among the participants.

The correlation between the difference of participants' performance in the two immediate free recall tasks (condition of semantically similar items and condition of semantically dissimilar items) and the participants' score on the creativity test revealed a significantly strong negative correlation (Pearson's r revealed an $r = -.823$). The negative correlation allows specific assumptions about the effect of individual differences on the ability of participants to correctly recall words from the lists. The calculation of the difference between participants' performance in the two immediate free recall tasks clearly demonstrated that participants used different strategies in different working memory tasks according to their individual differences (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015, Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). All the participants used an automatic strategy based on crystalised semantic relations between the items (the semantic properties of the items thus had

significant impact on the recall strategy) in order to recall lists containing semantically similar items (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). However, as hypothesised in this study and indicated by previous research, in lists containing semantically dissimilar items the employment of this technique (semantic similarity effect) was not applied at the same level by all participants (Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999). Less creative individuals recalled the items on the basis of phonological loop procedures (thus, the semantic properties of the items did not have a significant impact on the recall strategy) (Baddeley, 2012). This assumption was clearly supported because the advantage of the recall strategy based on the semantic similarity of the items was not applied at the same level by all participants on both conditions (semantically similar items and semantically dissimilar items) as performance was decreased on semantically dissimilar items. Furthermore, this assumption was also supported by the correlations analysis of the difference performance between the two onditions and creativity. This dimension will be reported and analysed extensively in the next section. In other words, first there was a big difference between performances in the two immediate free recall tasks and, secondly, this difference was negatively correlated with the creativity score. Thus, as creativity increases the difference between the two immediate free recall tasks is significantly reduced. However, as previous research indicates (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015, Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015) the effect of semantic similarity and its reductions according to the referent task is still present. It has to be stressed that the overall performance in the two conditions when is not tested against the factor of creativity has significantly different qualitative and quantitative characteristics (for specific quantitative data refer to the results section). As creativity increases we are unable to observe any causation effects but rather an effective elaboration of creative techniques within the same individual performance. This is clearly supported by research in working memory and creativity (Campoy and Baddeley 2008, Hanley and Bakopoulou, 2003, Campoy, Castellà, Provencio, Hitch & Baddeley, 2015) Thus, we can observe that the more creative individuals attempted to elaborate recall strategies based on the semantic properties of the items, and, more importantly, they were effective in their use of semantic strategies.

The explanation indicating that semantic encoding in working memory is based mainly on two theoretical approaches. The first is the multicomponent working memory framework (Baddeley, 2000, Campoy, Castellà, Provencio, Hitch & Baddeley, 2015) which proposes that the episodic buffer provides a link between long-term and working

memory, accounting for the short-term effects of semantic encoding. The second approach is based on neuropsychological research indicating a separate semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011). Literature attributes the selection of the most appropriate strategy in immediate serial and free recall to the characteristics of the processed items and the conditions under which the process is carried out (Campoy & Baddeley, 2008, Hanley and Bakopoulou, 2003). Verbal information encoding in working memory tasks is a consequence of automatic and/or controlled, attention demanding mechanisms of strategic retrieval and encoding (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Furthermore, research on the retrieval of verbal items supports the distinction between a fast, automatic activation of mainly phonological or partially semantic representations and a slower, more controlled, and strenuous mechanism of deep semantic strategic retrieval (Whitney, Grossman & Kircher, 2009; Gold et al., 2006; Badre & Wagner, 2002).

This idea and relevant research findings indicate that in a range of working memory conditions automatic activation (i.e. phonological strategy) is not sufficient, resulting poor performance in recalling accuracy (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012; Tse, Li & Altarriba, 2011). Thus a deep strategic retrieval is required in order to increase performance (Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999, Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015). The advantage of a deep word retrieval strategy is based on semantic encoding and especially the semantic similarity strategy and is explained by the redintegration model of Saint-Aubin and Poirier (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999). According to the model, long-term memory factors, such as semantic similarity, contribute to performance in immediate free and serial recall (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999). To account for this effect, a reconstruction hypothesis is often put forward. The present results are compatible with a version of the reconstruction hypothesis suggesting that a large memory search set is called upon at recall (Stuart & Hulme, 2000; Hulme, Maughan & Brown, 1991). The general assumption of the model indicates that at recall, phonological representations set up by its presentation are thought to be degraded and undergo a reconstruction process calling upon long-term knowledge of the to-be-recalled words. Broadly put, long-term knowledge of the language is be called upon to fill in the gaps left by degradation.

This idea is consistent with the findings of the present study. Analysis of the present study's data revealed a difference between the two conditions indicating the adoption of different strategies. When a semantic strategy was applied the performance was better (condition of semantic similar items). On the other hand, with regard to lists containing semantically dissimilar items, we observed an overall limited employment of semantic strategies. However, this absence, as discussed above, could not be totally accepted as there were variations accordingly to the levels of creativity.

In summary, we can clearly see that participants used different encoding and recall strategies. The effect of the referent task determined the implemented encoding and recall strategy (phonological or semantic) although this effect did not have the same power on all of the participants. The less creative individuals chose the strategy indirectly directed by the task itself (semantic strategy for semantically similar lists and phonological strategy for semantically dissimilar lists) while the more creative individuals chose a strategy (semantic strategy for both lists) according to their needs.

The notion of switching between strategies, as indicated by the results of the present study, is supported in literature. The assumed switch between semantic and phonological strategies in the present experiment determined participants' performance in recalling verbal information. Thus, before we proceed to the evaluation and explanation of the factors that determine the adoption of each strategy, it is very important to link previous research with the results of the present study. In particular, all three applied methods in testing the main hypothesis of the research indicate one conclusion. The correlation between the difference in the participants' performance in the two immediate free recall tasks and their score on the creativity test, the partial correlation between creativity and recall in semantically dissimilar lists, as well as the third method, all indicate that creative individuals attempt to use complicated recall strategies based on the semantic properties of the items.

Studies conducted by Campoy and Baddeley (2008), Hanley and Bakopoulou (2003) and Logie, Della Sala, Laiacona, Chalmers and Wynn (1996) argue that the switch between phonological and semantic strategies is a standard phenomenon in verbal short-term memory tasks. The ability of a subject to switch between a phonological and a semantic strategy relies on the characteristics of the task, mainly the instructions, and the individual differences between the participants. It is apparent as the findings of the present study indicate that the employed strategies during working memory tasks is a significant factor that could affect, positively or negatively, not only

the performance but also more importantly the quality of the working memory process outcome.

Campoy and Baddeley (2008), Hanley and Bakopoulou (2003) and Logie, Della Sala, Laiacona, Chalmers and Wynn (1996) in regard to switching between a phonological strategy and a semantic strategy, significant findings have been reported that allow a direct link to the present study. They conclude in summary that the minimisation of phonological effects can be interpreted on the basis of an adopted semantic strategy during encoding and recall. It should be noted, however, that in this case, the semantic strategy does not only assist working memory task performance but fundamentally changes the gravity of phonological factors. The results of those studies as well as the findings of the present study reflect the significance of semantic strategies and most importantly signify the importance of individual differences in working memory tasks procedures.

More specifically, the correlation of the difference between the two recall conditions and creativity as well as the partial correlation between creativity and semantically dissimilar items indicate that creative individuals adopt a semantic encoding and recall strategy in semantically dissimilar lists while less creative individuals employ a phonological strategy. It is therefore apparent that a closer examination of the employed strategies during working memory tasks is a significant factor that could affect, positively or negatively, not only the performance but also the quality of the working memory process outcome. It is important not to forget the hypothesis indicating that these processes affect the organisation of long-term memory representations and its foundation strategies, especially when considering the significance of the collaboration between long-term memory and working memory. Furthermore, a distinction between automatic and controlled strategies must be taken into consideration.

Verbal short-term memory has traditionally been perceived as relying on phonological encoding/phonological strategies and maintenance of representations. Furthermore, it has long been apparent that semantic encoding is also present during working memory processes, significantly facilitating immediate recall of verbal information. This concept has mainly been supported by studies investigating the semantic similarity effect. The interpretation of semantic encoding in working memory is therefore based primarily on two theoretical approaches. The first is the multicomponent working memory framework (Baddeley, 2000) proposing that the episodic buffer provides a link between long-term and working memory, accounting for the short-term effects of semantic

encoding. The second approach is based on neuropsychological research, indicating a separate semantic buffer within working memory. All of these studies suggest the selection of the most appropriate strategy in terms of the characteristics of processed items and the conditions under which processes are carried out (Campoy & Baddeley, 2008). In particular, verbal information encoding in working memory tasks is a consequence of automatic and/or controlled attention demanding mechanisms of strategic retrieval and encoding (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015). Research into the retrieval of verbal items supports the distinction between a fast, automatic activation of mainly phonological or partially semantic representations and a slower, more controlled, and complex mechanism of deep semantic strategic retrieval (Badre & Wagner, 2002; Gold et al., 2006; Whitney, Grossman & Kircher, 2009). This notion, and the relevant research findings, indicate that in a range of working memory conditions automatic activation is not sufficient and a deep strategic retrieval is required. The findings of the present study clearly indicate that switching between phonological and semantic encoding and recall is possible and observable. It is reasonable to presume therefore that this distinction is applied to working memory and long-term memory, indicating that the creative strategies that underpin creative behaviour might have also a significant effect in encoding and recall processes. The main reason for the existence of interpretation differences in verbal short-term memory relies on the adapted strategies, either phonological or semantic (Campoy & Baddeley, 2008). Although the use of a phonological strategy for recalling verbal information is considered predominant, under certain conditions or population characteristics the use of phonological strategy is partially abandoned in favour of a more reliable semantic strategy. There are a number of instances of theoretically important results in which major inconsistencies appear to have resulted from switching between phonological encoding and another strategy, probably semantic (Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996). In summary the present findings indicate not only a switch between semantic and phonological strategies but also a distinction between automatic and controlled strategies.

The literature provides support for the idea that semantic encoding in working memory tasks relies on strategic mechanisms, either automatic or controlled. However, there are contradictions over the question of which type of strategy is applied in specific tasks and their effect gravity as well. These dichotomies are mainly derived from the different characteristics of the measurement methods. As Miyake, Friedman, Emerson, Witzki, Howerter and Wager (2000) point out, evaluation of the employed strategies

with regard to working memory tasks has specific weaknesses derived mainly from the individual differences spectrum. They stress the existence of differences in terms of the employed strategies not only between subjects but also within the same subjects, not only on different tasks but even within the same task:

> Complex executive tasks tend to suffer from relatively low internal and/or test–retest reliability. Although the reasons for the low reliabilities are not completely clear, one possibility is that individuals adopt different strategies on different occasions (or even within a session) when performing these tasks. Also, the involvement of executive control functions is generally considered strongest when the task is novel (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000, p. 53).

The findings of the present study provide valid information about the existence of differences in terms of the employed strategies in immediate free recall tasks. The analysis reveals that creative individuals are able to apply semantic recall and encode strategies in tasks which do not facilitate such semantic processing (condition of semantically dissimilar words). The ability of creative individuals to establish associations within items (a critical characteristic of the applied semantic strategy) during working memory processes is clearly supported by the cognitive mechanisms underpinning creativity.

The findings of the present study also indicate for creative individuals a slower, more controlled, and strenuous mechanism of semantic strategic retrieval was adopted in support of, or as an alternative to, the typical phonologically based strategy for lists of semantically similar items. This demonstrates a situation in which automatic semantic activation is not sufficient, and a controlled semantic strategic retrieval is required in support of the typical phonologically based strategy. In contrast, less creative participants relied on the typical phonologically based strategy, resulting poor performance. This assumption was firstly revealed by the strong positive correlation between working memory performance on lists of semantically dissimilar items and creativity, and secondly by the strong negative correlation in the difference between the two recall conditions and creativity. We can assume that higher performance is the result of a semantic strategic retrieval which is clearly supported by the literature. (Note: the advantage of semantic strategies over the phonological was extensively covered above thus only significant references are presented here: Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012).

In terms of the use of controlled strategies in verbal working memory tasks we can take this one step further and suggest the possibility that participants engaged in elaborative strategies of controlled semantic encoding in order to improve their performance in the condition of semantically dissimilar items. Such controlled semantic strategies could involve, for example, the establishment of semantic links between words and the generation of stories or visual scenes. The assumption that semantic encoding in working memory tasks relies on controlled processes is supported by neuropsychological studies (Whitney, Kirk, O'Sullivan, Lambon Ralph & Jefferies, 2011; Badre, Poldrack, PareBlagoev, Insler & Wagner, 2005; Badre & Wagner, 2002; Wagner, Paré-Blagoev, Clark & Poldrack, 2001). In addition, evidence for the importance of strategies of elaborative encoding emerges from studies showing that the adoption of this kind of semantic strategy can eliminate phonological effects usually considered the hallmark of verbal short-term memory, such as the word-length effect or the phonological similarity effect (Campoy & Baddeley, 2008; Logie, Della Sala, Laiacona, Chalmers & Wynn, 1996).

Further support for a controlled semantic encoding as revealed in this study is provided by Whitney, Grossman and Kircher (2009). They conducted a study to test the hypothesis of two distinctive neural networks engaged in semantic encoding and retrieval. They argue that the frontoparietal network seems to support bottom-up related retrieval processes and is based on brain regions that have been linked to semantic integration and universal attention as well as working memory functions. This process is characterised as automatic. In contrast, top-down control seems to be more restricted to structures of executive semantic processing and is particularly sensitive to different kinds of retrieval manipulations (that is, controlled versus automatic). For a successful recovery of meaning, a flexible adjustment of top-down and bottom-up regulation is required. Thus, in the present experiment the participants probably applied a top-down control depending on semantic encoding.

In addition, the assumption that the participants scoring high in creativity attempted a controlled semantic retrieval in the condition of semantically dissimilar items is supported by the findings of Hoffman, Jefferies and Ralph (2011). In their experiment they assumed that strongly semantic similar words would activate very similar semantic representations in long-term memory. This situation is similar to the condition of semantically similar words in the present study. Therefore, a semantic relationship is established with little need for controlled processing. In cases where the

association is weaker, for this study that is the condition of semantically dissimilar words, a strategy with greater control is required in order to activate the relevant shared attributes and consequently to establish any potential relationship between the items. This tendency is connected to the requirement for a more controlled, flexible access to semantic knowledge than is available in cases where the criterion of category membership is apparent or commonly established. They conclude that the critical factor influencing the individuals' semantic working memory is not the amount of semantic information they have to retain but rather the cognitive control demands of performing the necessary semantic judgments.

These assumptions are supported also by Campoy, Castellà, Provencio, Hitch and Baddeley (2015). They hypothesise that specific examples of semantic encoding in standard verbal short-term memory is a consequence of controlled, attention demanding processes of strategic semantic retrieval and encoding under specific circumstances. They also emphasise the importance of individual differences, noting:

> The present study shows that semantic encoding in standard verbal STM tasks (immediate serial recall of unrelated words) does not depend on the participation of controlled semantic strategies. It is important to note, however, that this does not mean that participants cannot implement this kind of strategy in certain circumstances, as suggested by the fact that the standard phonological effect in STM is abolished when participants are explicitly instructed to use a semantic strategy (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015 p. 775).

Thus, on the basis of the present study's findings the individual characteristics and specifically creativity competence can be seen to critically affect cognitive control.

The importance of individual differences and especially creativity on controlled semantic encoding and retrieval is evident in research on divided attention. The encoding process requires attention and this is under the individual's conscious control (Naveh-Benjamin, Guez & Maron, 2003). Anderson, Green & McCulloch, 2000 argue that divided attention during encoding reduces encoding related brain activity in the left inferior prefrontal cortex, an area shown in other studies to be associated with deep strategic semantic processing. This suggests that divided attention could affect deep strategic semantic processing. However, recent studies have provided different results. In Craik and Kester's (2000) study results point towards a mechanism other than the degree of strategic elaboration underlying the effects of divided attention at encoding on later memory performance. These findings indicate that controlled strategies could

operate irrespective of the negative or positive effects of automatic mechanisms on effects such as divided attention. Thus in the condition of semantically similar words in the present study, the participants applied controlled semantic encoding irrespectivelly to the phonological strategy.

The variation in performance in terms of semantically dissimilar words according to creativity indicates that individual difference is a more crucial factor than the characteristics of the task when considering the employment of specific semantic strategies. This conclusion partially contradicts the assumptions of Soto, Hodsoll, Rotshtein and Humphreys (2008). They argue that high cognitive load might in fact automatically lead to a degradation of the items held in working memory, as a result of increased inter item competition for limited resources. This assumption leads to a conclusion that the use of controlled strategies in working memory could be significantly affected by the characteristics of the task. However, the findings of the present study indicate that individual differences is indeed a crucial factor which can override the effects caused by the characteristics of the task. It must be noted that Soto, Hodsoll, Rotshtein and Humphreys (2008) did not include any experimental manipulation targeting individual differences.

Relevant to the distinction between automatic and controlled strategies is the interpretation of the present findings indicating that creative individuals use controlled semantic encoding and recall when faced with semantically dissimilar items while they employ an automatic semantic strategy when dealing with semantically similar items. The advantage gained in connection with semantically similar items is evident and is only partially inhibited, as specific executive functions are elaborated. Strategic retrieval, shifting strategies and selective attention all allow creative individuals to reduce their tendency to produce multiple associations between items on the lists and therefore to achieve higher performance when dealing with semantically similar items over semantically dissimilar items. As Fournier-Vicente, Larigauderie and Gaonac'h (2008) clarify, strategic retrieval refers to the ability to prevent inappropriate information from interfering with the retrieval of the appropriate information from long-term memory. It involves an active memory search as well as active suppression of information.While this information might have automatically activated its presence is irrelevant for the specific task and it may actually interfere with current strategic search and retrieval operations. Shifting refers to the ability to suppress a response strategy or a mental set that has become inappropriate when moving between multiple tasks,

operations or mental sets. Finally, selective attention refers to the ability to prevent information that is irrelevant to the task from interfering with choice of target information.

However, as observed in the present analysis, the positive effect of the aforementioned executive functions only reduced the tendency to produce multiple associations between the items on the lists and did not eliminate it. This finding is supported by the results of the correlation between creativity and performance in the condition of semantically similar items, which revealed a small negative correlation. The positive effect of strategic retrieval, shifting strategies and selective attention is further supported by the study conducted by Fournier-Vicente, Larigauderie and Gaonac'h (2008). This study reveals that strategic long-term memory retrieval processes and many other complex executive constructs can undoubtedly be identified and partially placed under one function, the central executive.

The establishment of semantic associations between the to-be-recalled items in both conditions has a significant positive effect while failing to adopt semantic strategies hinders recall (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Baddeley, 2012; Larigauderie, Michaud & Vicente, 2011; Stuart & Hulme, 2000). This tendency was also observed in the present experiment. Participants with high creative abilities managed to use semantic strategies in the condition of semantically dissimilar items, establishing semantic associations in lists of dissimilar items. The elaboration of semantic strategies by creative individuals, resulting in improved performance, in the condition of dissimilar items, was clearly observed. Thus the analysis revealed a positive correlation between creativity and performance in terms of of semantically dissimilar items. The same assumption was also derived from the negative correlation between creativity and the difference between the two semantic similarity conditions. The participants used phonological and semantic strategies in different working memory tasks according to their individual differences. All the participants used an automatic strategy based on crystalised semantic relations between the items in order to recall lists containing semantically similar items. However, as predicted by previous research (Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999) this strategy was not applied in relation to lists containing semantically dissimilar items. Less creative individuals recalled the items on the basis of phonological loop procedures while creative individuals attempted to use recall strategies based on the semantic properties of the items. Perhaps more importantly they also effectively used

semantic strategies. Semantic retrieval of the lists was therefore shown to be able to proceed quickly and effortlessly or be characterised by a controlled search for candidate lexical items and a subsequent selection process.

As the study of Whitney, Grossman and Kircher (2009) reveals that for the successful recovery of meaning, a flexible adjustment of top-down and bottom-up regulation is required, leaving unattended the individual differences. This allows space for assumption of the employment of different strategies according to a controlled decision process. In other words, the characteristics of creative thinking can establish an efficient contextual environment that supports a controlled semantic environment.

In most problem solving attempts, individuals try to recall and choose, available implemented solutions from the past (Csikszentmihalyi, 1990b). Further, as Freyhoff, Gruber and Ziegler (1992) indicate, individuals often choose the first available solution identified. This assumption was also observed in the present study and marked a significant difference between performance on the condition of semantically similar items and the condition of semantically dissimilar items. In contrast, creativity requires the production of novel problem solutions. This necessitates individuals producing innovative solutions that offer answers to the relevant problems. In the present study the problematic situation involved the recall of words, specifically words relating to semantically dissimilar items. Choosing the first available solution in this case, that is a phonological strategy, did not contribute effectively to creativity. Moreover, in the specific condition of the experiment solutions implemented in the past were inapplicable.

Creativity necessitates the generation of novel, alternative problem solutions or, in the present situation (condition of semantically dissimilar words), remote associations between the words. It is very common to change goals and situations when standard solutions or predefined goals cannot provide an appropriate solution. Under these circumstances adaption to new goals and situations, removal of barriers to reaching old goals, and the improvement of old solutions are the only ways to succeed. These processes can all be characterised as typical creative processes (Csikszentmihalyi, 1990b).

The findings of the present study indicate that creative individuals adopt a semantic strategy when faced with semantically dissimilar items. In order to establish connections between the presented items they proceed to remote associations, which are based on associative processing. Associative processing refers to the activation of

mental networks consisting of objectively (the association is observed by the majority of the population) and subjectively associated concepts or mental items (Mednick, 1962). These associative mental networks are structured into an associative hierarchy (Brophy, 2001) demonstrating observable relations that are high in the hierarchy while others are low (Sternberg, 2003). It must be remembered that these hierarchies refer to associations between the items and are not hierarchies of the items themselves.

A creative product requires the activation of associations that are not commonly observed in the population. This is achieved when a stimulus cues a semantic representation which in turn activates another mental item until the activation reaches the appropriate/effective association (Brophy, 2001). In other words, creative ideas occur when more uncommon elements in lower positions in the associative hierarchy are generated or activated. Analytical reflections on associative processes in creativity research argue that creative products or ideas are generated through the recombination of existing elements. This is the strategy participants followed in the condition of semantically dissimiar items. This idea highlights the importance of working memory in associative processing and consequently the importance of the redintegration model (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Benedek, Konen & Neubauer, 2012).

Furhtermore, the findings of the present study support the idea of associative hierarchies. For example, people who score low in creativity normally have steep associative hierarchies (that is, the gradient of associative response strength for available associations to a given concept is steep, with only few associations showing high associative response strength), while highly creative people usually reveal flat associative hierarchies. In other words, creative subjects demonstrate more flexible associative links in their mental network and consequently are able to connect or disconnect associative relations more fluently than subjects described as less creative. This tendency could be one reason for developing more efficient creative problem solving abilities and behaviours. Also, individuals who have flatter associative hierarchies also choose solutions according to conventional associates. However, the effect of these associative hierarchies is not strong enough to allow access to, or generation of, more remote associates. However, under specific circumstances this accessibility leads to the generation of more uncommon, or rather creative, ideas and products (Mednick, 1962). This idea is also supported by Rossman and Fink (2010). They conclude that the findings of their research support the hypothesis presented by

Mednick (1962) and his influential theory of individual differences in associative hierarchies in the context of creative cognition. In particular, they support the idea that more creative people perceive the associative distance between the unrelated items pairs as being shorter than less creative people. In other words, more creative individuals have a more flexible associative network. The development of a creative idea or product requires the subject to temporarily inhibit conventional tendencies of information processing and build new connections between stimuli and mental representations. Rossman and Fink (2010) hypothesise that this tendency is a characteristic linked to the creative cognition.

On the basis of these approaches specific assumptions can be presumed. For example, people scoring low in creativity normally have steep associative hierarchies (that is, the gradient of associative response strength for available associations to a given concept is steep, with only few associations showing high associative response strength). In contrast, highly creative people demonstrate flat associative hierarchies. In other words, creative subjects show more flexible associative links in their mental network and consequently they are able to connect or disconnect associative relations more fluently than subjects who scored low in an RAT. Therefore, as non creative individuals develop strong associative hierarchies in terms of solving problems but do not generate of novel reactions to stimuli and problems, they perform poorly in the condition of semantically dissimilar items. Thus, the subjects that scored low in creativity minimise the generation of solutions to a small number of common and stereotypical options as in the condition of semantically similar items. In contrast, individuals who have flatter associative hierarchies commonly to choose solutions according to conventional associates. The effect of associative hierarchies is not strong, allowing access or generation to more remote associates. This accessibility facilitated the generation of more uncommon or creative ideas and products, and therefore the creative individuals demonstrated higerh performance in the condition of semantically dissimilar items.

The findings of the present study contribute to the hypothesis of a direct relationship between creativity and working memory. To date, only a few studies have investigated the relationship, and have done so indirectly. They assume that working memory benefits creativity for it enables the individual to maintain attention on the task and prevents undesirable mind wandering (De Dreu, Nijstad, Baas, Wolsink & Roskes,

2012). The present study reveals that creativity and creative strategies can significantly affect the strategies incorporated in working memory processes.

7.2.2 Semantic similarity and immediate free recall — the role of stable semantic networks and semantic encoding

This section addresses the findings of the study related to the observed differences in working memory tasks between the conditions of semantically similar items and semantically dissimilar items. General tendencies with regard to the relationship between working memory capacity and creativity will be also discussed in connection with the condition of semantically similar items.

7.2.2.1 The observed differences in working memory tasks between the conditions of semantically similar items and semantically dissimilar items

The difference in performance between lists containing semantically similar items and lists containing semantically dissimilar items was tested using an ANOVA. Analysis compared the difference between females and males as well as between the conditions of verbs and nouns. The ANOVA revealed a significant main effect of the factor of semantic similarity F-value (1 – 274) of .145 ($p = 0.703$) representing a significantly large effect size (partial Eta squared) of .683, demonstrating that nearly 68% of the variation in the number of correctly recalled items in the immediate free recall task can be accounted for by differing the semantic similarity of the presented items. The distinct advantage for immediate serial recall of lists comprising items from the same semantic category over lists containing words from different semantic categories is compatible with the updated version of the reconstruction hypothesis, suggesting that a large memory search set is called upon at recall in immediate free recall tasks: associative link hypothesis (Stuart & Hulme, 2000; Hulme, Maughan & Brown, 1991) and the computational/network models (Larigauderie, Michaud & Vicente, 2011). Thus, the present findings are mostly compatible with Baddeley's multicomponent model (Baddeley, 2012) and the redintegration hypothesis as proposed by Saint-Aubin, Ouellette and Poirier (2005).

The argument indicating that long-term memory factors, such as semantic similarity, contribute to performance in immediate free and serial recall, is well supported by scholarship (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999). To account for this effect, a redintegration hypothesis is often put forward. By analogy, the redintegration hypothesis can also be applied to the findings of the present study. Both Baddeley's

multicomponent model (Baddeley, 2012) and the redintegration hypothesis can account for the effect of long-term memory factors by suggesting that long-term knowledge of the to-be-recalled items was implemented during processing and at retrieval in the present study. The general assumption of the model is that at recall, phonological representations set up by its presentation are thought to be degraded and undergo a reconstruction process calling upon long-term knowledge of the to-be-recalled words. This long-term knowledge of the language is essentially called upon to fill in the gaps left by degradation. According to the reconstruction hypothesis, in the present experiment the lists containing semantically related words were more sucessfully recalled than lists containing semantically related words because, at recall, the category shared by list items increased the probability of retrieving the appropriate long-term representations. This was either because the category provided an additional retrieval cue (Saint-Aubin & Poirier, 1999; Poirier & Saint-Aubin, 1995; Crowder, 1979) or because long-term representations of similar items were more activated due to their long-term associative links (Hulme, Stuart, Brown & Morin, 2003; Stuart & Hulme, 2000).

When we apply the redintegration model (Saint-Aubin, Ouellette & Poirier, 2005) to the present findings it can be assumed that the participants firstly encode the verbal materials into their phonological forms. This is also suggested by Baddeley's multicomponent model (Baddeley, 2012). They encode each list of words (regardless their semantic similarity condition) on the basis of phonological properties. These encoded forms of the words are continuously rehearsed and this rehearsal automatically codes the temporal order information for the items. However, during the probe phase (the time between the presentation of the items and the recall phase), these phonological forms can become degraded, through either decay or interference. The subjects thus initially attempt to retrieve the degraded phonological forms in short-term memory. At this stage they also proceed to an initial semantic processing. The result of this is either the establishment of a semantic relationship between the items (condition of semantically similar items) or partial establishment (condition of semantically dissimilar items). However, a deeper semantic and phonological encoding is then required for the last condition. Therefore, the participants finally match the encoded items with the stored phonological and semantic information in long-term memory.

The semantic similarity effect, according to Saint-Aubin and Poirier (1999) and Saint-Aubin, Ouellette and Poirier (2005), had an additional effect during the recall

phase. Item redintegration for related items was facilitated by participants' long-term knowledge. The category node appears to have been implemented as a cue to delimit the number of potential recall candidates within semantic categories and as a consequence the redintegration process was more effective than unrelated items. For participants in this study, word meanings were retained and accessed by working memory and, more specifically, by the episodic buffer. These processes were independent from phonological and visual codes (Hamilton & Martin, 2005; Shivde & Thompson-Schill, 2004; Baddeley, 2003; Haarmann & Usher, 2001; Baddeley, 2000; Potter, 1993). However, it must also be noted that individual differences during the initial semantic encoding within working memory nevertheless had a significant effect on the process. As discussed above, participants' performance and processes during these phases was highly affected by individual differences in regard to their creative abilities competence. In general terms, however, both the creative and less creative participants did use semantic similarity as a valuable cue resulting in an advantage for the immediate serial recall of lists comprising items from the same semantic category over lists containing words from different semantic categories.

This advantage for the immediate serial recall of lists comprising items from the same semantic category over lists containing words from different semantic categories can also be explained on the basis of computational/network models (Larigauderie, Michaud & Vicente, 2011). These models offer a slightly different perspective in regard to the encoding of semantic information in working memory and the extent of collaboration between working memory and long-term memory. They explain the effect of semantic similarity on the basis of a semantic buffer within working memory (Larigauderie, Michaud & Vicente, 2011). According to this view, the participants in the present experiment extensively encoded the semantic information within working memory in the form of a semantic buffer. They detected the semantic similarity of the items in the condition of related words, and the absence of semantic similarity in the condition of unrelated words, before proceeding to match the encoded items with the stored phonological and semantic information in long-term memory. This subtype of working memory is known to be responsible for the encoding and processing of semantically similar words (Haarmann, Cameron & Ruchkin, 2003; Haarmann & Usher, 2001).

Computational or network models propose that verbal information is processed in working memory on the basis of interconnected networks where lexical and

phonological representations are interconnected. In particular, an interactive network model is necessary in order to explain the effect of semantic information (Roodenrys, Hulme, Lethbridge, Hinton & Nimmo, 2002; Roodenrys, Hulme, Alban, Ellis & Brown, 1994). According to this approach letter, phonemic and lexical representations are mutually activated and compete with each other. Therefore, in the condition of semantically similar items, the available lexical information is a crucial cue for correctly recalling the lists. In contrast, in the condition of semantically dissimilar items, the absence of lexical information led the participants to access only phonemic representations and not lexical resulting in less effective recall. While this approach might provide a reasonable explanation for the general effect of semantic similarity it does not provide explanation of the distinctive differences between the participants performance in regard to their creativity competence. This is because computational or network models do not incorporate the factor of individual difference and its effect on the implemented strategies.

Another explanation for the semantic similarity effect in the present findings can be seen in the approach of Stuart and Hulme (2000). Their associative link hypothesis was based on the reconstruction hypothesis (Hulme, Roodenrys, Schweickert, Brown, Martin & Stuart, 1997). Therefore, the associative link hypothesis is similar to Saint-Aubin, Ouellette and Poirier (2005) and Poirier, Saint-Aubin, Mair, Tehan and Tolan's (2015) redintegration model, overlapping to some extent. Hulme et al.'s (1997) item redintegration theory assumes that the recall of the to-be-remembered word is affected by other words presented in the same context.-According to this concept, when two words (for example,teacher and student) are strongly associated, the encoding and later the recall of one item can activate and facilitate the encoding and the recall of the other (Nelson, McEvoy & Schreiber, 2004). This model can be used to explain the effect of semantic similarity observed in the present study.

According to the associative link hypothesis, recall is facilitated when the pre-existing associative strength between the presented items in semantic memory becomes stronger — in this case, the condition of semantically similar items. In particular, the encoding and recall of a word (for example, teacher) activated related words (for example, student). This activation of words facilitated their accessibility and in turn enhanced the encoding and recall of these items. Because the spreading activation relied on the inter-item associative strength between the target words, a strong inter-item association among the presented words resulted in a higher item recall performance.

Significantly, while this model incorporates the factor of individual differences in the implemented strategies, it does not account for the effect of creativity. Therefore it can only provide an efficient explanation for the difference in performance between lists containing semantically similar items and lists containing semantically dissimilar items.

The ANOVA analysis revealed that there was no significant main effects of the participant's gender and the grammatical category of the items. There have only been a few previous attempts to study the word class effect. One of the main analytical attempts was the study undertaken by Tehan and Humphreys (1988) in which they report a significant word class effect. Specifically, they note that the recall accuracy of content words (adjectives, nouns) is better than the recall accuracy of function words (prepositions, conjunctions, etc.). These findings indicate the importance of lexico-semantic factors in working memory. Additionally, their interpretation sees the word class effect as contributing to the long-term memory store as their findings could not be explained in terms of a stimulus frequency effect, thus indicating the importance of the episodic buffer.

Bourassa and Besner (1994) replicate and present similar results to the experiment performed by Tehan and Humphreys (1988). They carried out three related experiments, finding better recall for content words than function words, and generally confirming the word class effect. However, they also note that the word class effect disappeared when the two classes of words, content and function words, were equated for imageability. They interpret their findings by arguing that the grammatical class effect is thus a by-product of an imageability effect concluding that "imageability made a significant contribution to serial recall performance independently of the effects due to the articulatory loop" (Bourassa & Besner, 1994, p. 123). As the present experiment did not have any variation between content and function words the present findings could be compared with the aforementioned studies in regard to the expected absence of difference between nouns and verbs. As both of the grammatical categories are considered content words, is was not expected and confirmed that the contribution of a long-term memory representation did not have any effect on the recall accuracy of the presented items. Finally, there has been no previous study reporting any participants' gender effect on their immediate or serial recall performance.

In summary, semantically grouped words can thus be interpreted in terms of associations between working memory and long-term memory as well as strategies implemented at any stage. There is evidence that working memory is influenced by

semantic factors including the semantic similarity factor (Campoy & Baddeley, 2008; Martin, 2005; Haarmann & Usher, 2001; Walker & Hulme, 1999; Poirier & Saint-Aubin, 1995). According to the most supported and defined approaches, the effect of semantic similarity is accounted for firstly by the strategies employed during encoding and secondly by a two stage retrieval based framework. Using this framework at immediate recall, long-term information is used to process or reconstruct degraded phonological traces temporarily processed on working memory (Campoy, Castellà, Provencio, Hitch & Baddeley, 2015).

7.2.2.2 The relationship between creativity and working memory ability in recalling semantically similar items

In addition to exploring the role of the semantic similarity effect further analysis was carried to investigate the relationship between creativity and working memory ability in recalling semantically similar items. This was essential in order to compare the findings of the present study with findings indicating that creativity and working memory capacity have opposing characteristics, possibly in terms of diffuse attention (Takeuchi, et al., 2011; Tse, Li & Altarriba, 2011; Tse S. C., 2009). In particular, the correlation between working memory performance in lists containing semantically similar items and creativity performance was tested using a bivariate correlation test, Pearson's Product Moment Correlation (Pearson's r). The analysis revealed a very weak negative correlation coefficient $r = -.179$ between working memory performance in lists containing semantically similar items and creativity performance. This negative linear relationship was statistically significant, thus allowing secure interpretations. Furthermore, the analysis allowed the establishment of the assumption that in less demanding or simple tasks there is no (at least obviously observable) or even negative effect in terms of creativity (Yeh, Lai, Lin, Lin & Sun, 2015).

The results of the present study revealing weak negative correlation between working memory performance in lists containing semantically similar items and creativity performance are in partial conjunction with previous research (Takeuchi, et al., 2011; Tse, Li & Altarriba, 2011; Tse, 2009). Although there is some resemblance to previous research findings indicating a negative correlation between these variables (Tse, Li & Altarriba, 2011), the present study has additional significant methodological characteristics which distinguish it from previous interpretations. The main difference is focused on the employment of immediate free recall tasks with different characteristics (semantically similar items and semantically dissimilar) and their comparative analysis.

The present design and implemented analysis therefore allow an interpretation that finds on only a partial conjuction with previous findings. In addition, specific theoretical implications can be extracted. This idea is also supported by Martindale (1999).

As discussed above, it is well established that long-term memory factors, such as semantic similarity, contribute to performance in immediate free and serial recall (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015Saint-Aubin, Ouellette & Poirier, 2005; Saint-Aubin & Poirier, 1999). To account for this effect, a reconstruction hypothesis is often put forward. This hypothesis suggests that lists containing semantically similar words provide an advantage in recall as the category shared by list items increases the probability of retrieving the appropriate long-term representations, either because the category provides an additional retrieval cue (Saint-Aubin & Poirier, 1999; Poirier & Saint-Aubin, 1995) or because long-term representations of similar items are more easily activated due to their long-term associative links (Hulme, Stuart, Brown & Morin, 2003; Stuart & Hulme, 2000).

Thus, in the condition of semantically similar items in the present study, the participants used long-term memory associative links in order to more efficiently recall the presented words. They also used the shared semantic category as an additional retrieval cue. Efficient performance in the search was also not restricted to the items presented in the trial as participants made inferences with regard to plausible recall candidates. Previous scholarship on problem solving has suggested that individuals engage in an initial analysis before actually performing a problem solving activity. This task analysis often involves searches of long-term memory through episodic and semantic knowledge for relevant information or ideas that can be applied to the task (Gilhooly, Fioratou, Anthony & Wynn, 2007). In this study, the participants were able to recognise, at the presentation phase, the common semantic grounds of the words and use this strategy later in the reconstruction phase. In other words they applied a specific encoding and recall strategy. However, the employment of this strategy was more efficient for the less creative individuals as the creative participants adopted alternative strategies and only partialy adopted the obvious semantic similarity cue. This tendency had a negative effect on their performance in comparison to the less creative participants.

The findings of the present study are also in congruence with the reported pattern of activity during working memory in the precuneus among creative subjects, reflecting a reduced ability to suppress irrelevant cognitive activity during a cognitive task. The

precuneus is one of the regions that is deactivated during cognitive tasks (Takeuchi et al., 2011). Creative individuals are thus not able to inhibit or suppress cognitive activity irrelevant to the referent task performance (task unrelated thought) resulting in negative effects on their performance. On the other hand, less creative individuals manage to suppress irrelevant cognitive activity resulting in better performance.

Furthermore, it has been suggested that greater creativity might be achieved by using brain networks in which knowledge in one domain helps organise a quite different domain that might, nevertheless, share some attributes (Heilman, Nadeau & Beversdorf, 2003). In support of this idea it has been found that selective attention, which involves the ability to focus cognitive resources on information relevant to goals, can influence working memory performance (Gazzaley & Nobre, 2012), while both modality dependent working memory mechanisms and modality independent attention control mechanisms have an impact on insight problem solving (Chein & Weisberg, 2013). It must be noted that the analysis of the data in the present experiment indicates that participants did indeed employ the common tendency in activating all the possible associations between the items on the lists. As revealed in the ANOVA analysis between semantically similar and dissimilar items all the participants, including the creative subjects, detected, analysed and employed the common semantic ground in the condition of semantically similar words. This resulted in better performance in this condition.

Further, according to the speculation of Takeuchi, et al. (2011), creative individuals are unable to suppress seemingly unnecessary cognitive activity. They identify the obvious semantic similarity but are then constantly seeking to associate the represented items in different networks, searching for alternative associations or strategies. This tendency necessarily has an effect on their performance. These two networks usually “anticorrelate”; in other words, when one network is activated, the other is deactivated (Buchner, Mehl, Rothermund & Wentura, 2006). In terms of the present study, potentially as a result of the extended search in different networks the performance of more creative individuals was negatively affected. This was contrary to the less creative individuals who were able to identify and apply the standard semantic similarity strategy. This is demonstrated by the negative correlation between working memory performance in lists containing semantically similar items and creativity performance.

In summary, the data of the present study allow specific secure speculations. Firstly, the creative individuals did manage to recognise instantly at the presentation phase the common semantic ground of the words and use this strategy later at the reconstruction phase. Secondly, they were not able to inhibit or suppress cognitive activity irrelevant to the referent task performance. They sought to constantly associate the represented items in different networks (for example, seeking obvious semantic similarity between the items and alternative remote associations) searching for alternative associations or strategies. Thirdly, these networks usually "anticorrelate" such a that when one network is activated, the other is deactivated. Therefore, the search for alternative strategies resulted in an extended amount of information flowing into working memory. As a consequence, the more creative individuals had to sacrifice time and resources in order to cope with the selected strategy (Baddeley, 2012). They ignored the obvious semantic similarity and searched for alternative strategies with a resulting cost in terms of their performance. In contrast, the less creative individuals immediately choose as a recall strategy the obvious semantic similarity cues and as a result exhibited equivalent or even slightly better performances. This interpretation partially explains the negative or marginal correlation between creativity and working memory performance. However, the absence of positive correlation between the variables could not be extended in all working memory processes, as clearly indicated by the analysis of the main hypothesis of this study.

The advantage of less creative individuals over more creative ones could not be extended to all tasks, as proposed by Takeuchi, et al. (2011) and Yeh, Lai, Lin, Lin & Sun (2015). This correlation is only observed in the condition of semantically similar items and not in the condition of semantically dissimilar items. In terms of semantically dissimilar items the analysis revealed a very strong correlation between creativity and performance in working memory ($r = .835$). Comparison of those two analyses indicates that the correlation between creativity and working memory is highly dependent on the referent tasks. High demanding tasks (semantically dissimilar lists) allow and even require the implementation of creative abilities (Poirier, Saint-Aubin, Mair, Tehan & Tolan, 2015; Tse, 2009). In contrast, for low demanding tasks (semantically similar lists) there is no observable effect of creative abilities (Gilhooly, Fioratou, Anthony and Wynn, 2007; Poirier & Saint-Aubin, 1995). Furthermore, while creative individuals tend to generate and automatically use common solutions depending on their long-term memory they are also able to incorporate remote associations, regardless of the nature of the task. However, this implementation of alternative strategies has a significant cost

in terms of performance. This cost is clearly indicated by the difference in effectiveness of creative strategies between the conditions of semantically similar and dissimilar items in favour of the former. Therefore, the employment of specific strategies and the performance of working memory depends greatly on the referent task and individual differences.

7.3 Limitations

Studies that point to intelligence as a significant predictor of creative thinking indicate that executive processes related to intelligence also play a strong role in creative thought (Engle, Tuholski & Laughlin, 1999). In addition, working memory capacity is a well-documented executive ability that has been shown to strongly relate to fluid intelligence (Unsworth, Redick, Heitz, Broadway & Engle, 2009; Conway, Cowan, Bunting, Therriault & Minkoff, 2002; Engle, Tuholski & Laughlin, 1999). Thus, it would have been reasonable to test the correlation between creativity and working memory by also controlling the factor of intelligence. This factors was not included in the experiment of the present study for two reasons. Firstly, any analysis was performed within subjects and not between subjects minimising in this way any possible effect due to intelligence variation. Furthermore, the implemented working memory tasks sought to test the correlation between the variables on the basis of the adopted strategies and not the general psychometric properties. Thus, we can assume that any effect of verbal intelligence on participants' performance should have been extracted. However, this possibility cannot be easily excluded. Secondly, adding another element to the present study would have necessarily increased the required time for the completion of the experiment. Considering the importance of the characteristics of the experiment, it was therefore reasonable to exclude any verbal intelligence assessment.

7.4 Further research — proposals

Overall, the findings of the present thesis have specific implications for cognitive psychology research and specifically for the investigation of the strategies within working memory. The elaboration of activities in working memory tasks requiring creative strategies fulfills the methodological gap in relevant experimentations as suggested by Takeuchi, et al. (2011), Yeh, Lai, Lin, Lin & Sun (2015) and Campoy & Baddeley, (2008). According to Cowan (1999; 2000) and the properties of the episodic buffer in Baddley's (2012) model, working memory performance can be accounted for by a combination of information available in working memory and long-term memory representations. However, special consideration should be given to the question of

whether rapid long-term learning of new associations is achieved or not. If this is the case, further research is necessary to investigate if these associations are present in later working memory procedures. In other words, it is important for future research to test if, and for how long, the new associations between the presented items are available.

The findings of the present research indicate that the higher the creative abilities of an individual the higher the associations between items in working memory tasks. However, the present experiment does not provide information about the availability of these associations only in the specific task or in long-term memory. Further, specific questions can be derived from these assumptions. Could the generated association in the condition of semantically dissimilar items be available as automatic associations in other tasks? Do subjects with high creative abilities store the new associations and use them in future as stable associations or do they prefer to create new associations according to the characteristics of the referent task? Research concentrating on these questions could also shed light on other aspects as well. A possible experiment allowing insight into these questions could contain the presentation of lists of semantically unrelated items and after a period, the presentation of the same lists along with new similar lists of unrelated words. A possible difference between the old lists and the new lists and the responses of the participants in relation to creativity could provide valuable information for future research. In summary, such an experimental manipulation could be used as an indication of how new associations are stored in long-term memory and whether these new associations are present in working memory procedures.

Appendix 1

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Remote Associates Test

Οδηγίες : Παρατηρήστε στην κάθε ερώτηση τις τρεις λέξεις που παρουσιάζονται και γράψτε μια τέταρτη, η οποία σχετίζεται και με τις τρεις.

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2.	Λίρα	Γάμος	Σταυρός	_____
3.	Καρέκλα	Στρογγυλό	Πινγκ πονγκ	_____
4.	Υπολογιστής	Κολλάω	Γιατρός	_____
5.	Αίμα	Ουρανός	Μάτια	_____
6.	Παιχνίδι	Πιστωτική	Ευχές	_____
7.	Κενό	Ελέφαντας	Παρελθόν	_____
8.	Τετράγωνο	Χαρτόνι	Ανοίγω	_____
9.	Χαρτί	Φύλλο	Σκιά	_____
10.	Πεύκο	Πόνος	Νοσοκομείο	_____

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Appendix 2

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Ανακαλέστε και γράψτε τις λέξεις που προβλήθηκαν

Appendix 3

Department of International Studies
Faculty of Arts

MACQUARIE University
SYDNEY·AUSTRALIA

Τηλ: +61 (2) *9850 7031*
Φαξ: +61 (2) 98507054
Ηλ. Ταχ.: elizabeth.kefallinos@mq.edu.au

Κύρια ερευνήτρια / Επιβλέπουσα: Δρ Ελισάβετ Κεφαλληνού

Πληροφορίες Συμμετοχής και Δήλωση Συγκατάθεσης

Όνομα έρευνας: Επεξεργασία της ελληνικής γλώσσας δημιουργικά. Η επίδραση των δημιουργικών διεργασιών στη διαδικαστική μνήμη. Διερεύνηση των δημιουργικών διεργασιών σε φυσικούς ομιλητές των Ελληνικών.

Παρακαλείστε να συμμετάσχετε σε μια έρευνα για τη δημιουργικότητα και τη διαδικαστική μνήμη. Σκοπός της παρούσης έρευνας είναι να προσδιορίσει την πιθανή συσχέτιση ανάμεσα στη δημιουργικότητα και τη διαδικαστική μνήμη στον ελληνικό πληθυσμό και πιο συγκεκριμένα στην ελληνική γλώσσα.

Η έρευνα διεξάγεται στα πλαίσια της εκπλήρωσης των απαιτούμενων για την εκπόνηση διδακτορικής διατριβής με επιβλέπουσα την Δρ. Ελισάβετ Κεφαλληνού. (τηλ. [00612] 9850 7031, Ηλ. Ταχ.: Elizabeth.kefallinos@mq.edu.au) του Τμήματος Διεθνών Σπουδών.

Αν τελικά αποφασίσετε να συμμετάσχετε, θα κληθείτε να συμπληρώσετε ένα ερωτηματολόγιο για το επίπεδό σας στην Ελληνική γλώσσα έτσι ώστε να μπορέσει ο ερευνητής να εξασφαλίσει ότι όλοι οι συμμετέχοντες έχουν το ίδιο γνωστικό υπόβαθρο στην Ελληνική γλώσσα. Στη συνέχεια, θα σας παρουσιαστούν 30 ομάδες λέξεων και θα σας ζητηθεί να ανακαλέσετε όσες περισσότερες μπορείτε (κάθε ομάδα λέξεων θα παρουσιάζετε για μερικά δευτερόλεπτα). Μετά την ολοκλήρωση αυτού του μέρους, θα σας δοθούν 10 ομάδες των τριών λέξεων και θα κληθείτε να γράψετε για κάθε ομάδα μια τέταρτη λέξη η οποία σχετίζεται κατά τη γνώμη σας με τις τρεις λέξεις που παρουσιάστηκαν. Επιπροσθέτως, θα κληθείτε να απαντήσετε σε 3 ερωτήσεις σχετιζόμενες με την όλη διαδικασία. Οι απαντήσεις σας θα αξιολογηθούν με βάση τον αριθμό των ανακληθέντων λέξεων και την πρωτοτυπία τους. Για τη συμμετοχή σας στην έρευνα δεν θα πληρωθείτε. Η διαδικασία διαρκεί περίπου 40 λεπτά.

Όλες οι πληροφορίες, προσωπικές ή μη, οι οποίες συγκεντρώνονται καθόλη τη διάρκεια της έρευνας είναι εμπιστευτικές, εκτός αν προβλέπονται από το νόμο. Το στοιχεία κανενός συμμετέχοντος δε θα δημοσιοποιηθούν σε οποιαδήποτε δημοσίευση των αποτελεσμάτων. Τα δεδομένα θα αποθηκευτούν σε ένα υπολογιστή και θα είναι προσβάσιμα μόνο στην κύρια ερευνήτρια και στον ερευνητή. Μια περίληψη των αποτελεσμάτων των δεδομένων μπορεί να είναι διαθέσιμη ύστερα από αίτησή σας στην κύρια ερευνήτρια.

Η συμμετοχή στην έρευνα είναι εθελοντική: δεν είστε υποχρεομένος/η να συμμετάσχετε στην έρευνα και αν επιλέξετε να συμετάσχετε είστε ελεύθερος να αποσυρθείτε οποιαδήποτε στιγμή χωρίς να δικαιολογήσετε την απόφασή σας και χωρίς να έχετε οποιαδήποτε επίπτωση. Η συμμετοχή ή η μη συμμετοχή σας στην έρευνα δε σχετίζεται με την αξιολόγησή σας σχετικά με τις σπουδές σας και το πανεπιστήμιου στο οποίο φοιτάτε δεν έχει κάποια εμπλοκή στην έρευνα. Αν έχετε οποιαδήποτε ένσταση σε σχέση με θέματα δεοντολογίας μπορείτε να καλέσετε το Υπουργείο παιδείας και Θρησκευμάτων (τηλ. 001130 210-3442508).

Έχω διαβάσει και κατανοήσει τις παραπάνω πληροφορίες και όποιες ερωτήσεις έθεσα έχουν απαντηθεί ικανοποιητικά. Συναινώ να συμμετάσχω στην έρευνα και γνωρίζω ότι μπορώ να αποσυρθώ οποιαδήποτε στιγμή από την έρευνα χωρίς επιπτώσεις. Μου έχει δοθεί αντίγραφο αυτής της δήλωσης.

Macquarie University **T:** +61 2 98507005 F: +6161 2 98507054
NSW 2109 Australia **T:** +61 2 98507005 mq.edu.au

ABN 90 952 801| CRICOS Provider 00002J

APPENDIX 4

Department of International Studies
Faculty of Arts

Κωδικός συμμετέχοντος: _____ (συμπληρώστε έναν πενταψήφιο κωδικό)

Όνομα ερευνητή: Δρ Ελισάβετ Κεφαλληνού

Υπογραφή ερευνητή:_____ Ημερομηνία:___13/05/2015_____

Τα θέματα δεοντολογίας αυτής της έρευνας έχουν εγκριθεί από την Επιτροπή Ανθρώπινης Δεοντολογίας του Πανεπιστημίου Μακόρι - Macquarie University Human Research Ethics Committee-. Αν έχετε οποιαδήποτε παράπονα ή ενδοιασμούς σε σχέση θέματα δεοντολογίας της συμμετοχής σας στην έρευνα, μπορείτε να επικοινωνήσετε με την Επιτροπή διαμέσου της Διεύθυνσης, Δεοντολογία και Ακεραιότητα Έρευνας -Research Ethics & Integrity- (Τηλ. (00612) 9850 7854; ηλ. Ταχ. ethics@mq.edu.au). Οποιοδήποτε παράπονο θα αντιμετωπιστεί με εχεμύθεια και θα διερευνηθεί, καθώς και θα ενημερωθείτε για το αποτέλεσμα. Ακόμα, μπορείτε να επικοινωνήσετε με το Υπουργείο Παιδείας και Θρησκευμάτων (τηλ. 210-3442508) ή την Ελληνική Εταιρεία Ηθικής (τηλ. 210.5753121 ηλ. ταχ. info@ethics.gr).

(ΑΝΤΙΓΡΑΦΟ ΓΙΑ ΤΟΝ ΕΡΕΥΝΗΤΗ [ΣΥΜΜΕΤΕΧΟΝΤΑ])

Macquarie University **T:** +61 2 98507005 F: +6161 2 98507054
NSW 2109 Australia **T:** +61 2 98507005 mq.edu.au

ABN 90 952 801| CRICOS Provider 00002J

Appendix 4

Dear colleagues,

I hope you are well.

A research team from Macquarie University Australia has asked me to articulate this email. It concerns a research project investigating the relation between creativity and working memory in Greek language.

At this stage of the research a survey is conducted in order to collect valuable information.

The survey consists of one questionnaire and an experiment. The completion of the survey should take approximately 40 minutes.

Participation in this study is entirely voluntary and completely anonymous. The results of the data can be made available to you on line or via contacting the researchers. Your participation or non-participation has no bearing on your unit assessment.

If you decide to participate you have to visit the following url and follow the instructions.

https://mqedu.qualtrics.com/SE/?SID=SV_6oftX6usWxXDBsN

We would like to thank in anticipation for all your valuable contribution in time and comments.

Sincerely,

Dr Elizabeth Kefallinos, Head of Greek Studies, Macquarie University

Mr Ioannis Kalaitzidis, PhD candidate, Macquarie University

Appendix 5

MACQUARIE University

IOANNIS KALAITZIDIS <ioannis.kalaitzidis@students.mq.edu.au>

Final Approval - Issues Addressed - Ref. 5201500489

2 messages

Faculty of Arts Research Office <artsro@mq.edu.au> Wed, Aug 5, 2015 at 9:58 AM
To: Dr Elizabeth Kefallinos <elizabeth.kefallinos@mq.edu.au>
Cc: Faculty of Arts Research Office <artsro@mq.edu.au>, Mr Ioannis Kalaitzidis <ioannis.kalaitzidis@students.mq.edu.au>

Ethics Application Ref: (5201500489) - Final Approval

Dear Dr Kefallinos,

Re: 'Processing Greek Language Creatively The impact of creative processes on working memory Exploring creative processes in native Greek speakers.'

Thank you for your recent correspondence. Your response has addressed the issues raised by the Faculty of Arts Human Research Ethics Committee. Approval of the above application has been granted, effective 5/08/2015. This email constitutes ethical approval only.

If you intend to conduct research out of Australia you may require extra insurance and/or local ethics approval. Please contact Maggie Feng, Tax and Insurance Officer from OFS Business Services, on x1683 to advise further.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Dr Elizabeth Kefallinos
Mr Ioannis Kalaitzidis

NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 05/08/16
Progress Report 2 Due: 05/08/17
Progress Report 3 Due: 05/08/18
Progress Report 4 Due: 05/08/19
Final Report Due: 05/08/20

NB: If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:
http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:

http://www.mq.edu.au/policy/

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of approval to an external organisation as evidence that you have approval, please do not hesitate to contact the Faculty of Arts Research Office at ArtsRO@mq.edu.au

Please retain a copy of this email as this is your official notification of ethics approval.

Yours sincerely

Dr Mianna Lotz
Chair, Faculty of Arts Human Research Ethics Committee
Level 7, W6A Building
Macquarie University
Balaclava Rd
NSW 2109 Australia
Mianna.Lotz@mq.edu.au

IOANNIS KALAITZIDIS <ioannis.kalaitzidis@students.mq.edu.au> Thu, Aug 6, 2015 at 10:03 AM
To: Ioannis Kalaitzidis <ikpsyedu@gmail.com>, ioannis.kalaitzidis@mq.edu.au, pat korom <patkoromvokis@hotmail.com>

[Quoted text hidden]

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