Situation Models: A Framework to Study Reading Comprehension

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STATEMENT

This is to certify that this thesis represents an original piece of work and has not been submitted for a higher degree to any other university or institution. This thesis refers to work of others with due citations and includes references from published journals. Ethics Committee approval has been obtained (5201200035 -STUDENT).

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Overview

The ultimate goal of reading is comprehension (Nation, 2005). The ability to read and understand text is a critical part of the education experience, and the long term consequences of poor school achievement are well known. Difficulties with reading comprehension not only hold back an individual's learning and academic achievements but can also limit their employment options, social functioning in society, and life satisfaction (Ricketts, 2011).

Reading comprehension, however, is extraordinarily complex, and rather difficult to measure considering that it involves a number of cognitive processes that cannot be observed directly (Ricketts, 2011). Understanding written text not only requires recognising words, accessing their meanings, activating relevant background, and generating inferences, but also involves monitoring ongoing comprehension (Ricketts, 2011). It follows that effective strategies for reading comprehension instruction should draw upon cognitive theories, and must extend beyond supporting text-based processing (Koning & van der Schoot, 2013).

Models of reading comprehension accept that comprehension requires the reader to build a mental representation of the text (Nation, 2005). This mental representation of the text refers to the unique 'situations' described in the text (Zwaan & Radvansky, 1998). Situation models offer a useful framework to study reading comprehension and not only embody an individual's personal representation of the meaning of the text but also provide a way to study the processes involved in comprehension monitoring (Rinck & Weber, 2003).

The current thesis represents a first step towards investigating reading comprehension difficulties using a situation model framework. The first part of the

thesis is a review of literature on situation models. This review contains a broad discussion of situation models, and critically evaluates research findings with a focus on methodological issues. Specifically, the implications of these methodological concerns on the interpretation of research findings are discussed. The second part of the thesis describes an empirical study combining reading time and eye movement measures to study reading comprehension processes within the framework of situation models.

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Situation Models: A framework to Study Reading Comprehension

Comprehension is more than a straightforward process of combining word meanings. It involves creating mental representations that capture aspects of the micro-world created by the reader (Johnson-Laird, 1983; van Dijk & Kintsch, 1983) and refers to the people, spatial setting, actions, and events in the mental micro-world (Graesser, Millis, & Zwaan, 1997). This representation of the state of affairs or 'situation model' is associated with 'deep' understanding and involves the integration of prior knowledge with the information stated in the text (van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). A situation model can therefore be thought of as an extended mental representation of the people, objects, actions, and events involved in the text organized in a manner coherent with the reader's knowledge (Foltz, Britt, & Perfetti, 1996).

Theoretical Importance of Situation Models

There is general agreement regarding the theoretical importance of situation models (Therriault & Rinck, 2007). The authors van Dijk and Kintsch (1983) conceptualised situation models as being an integral part of building comprehension. They posit that situation models are required to explain how a reader is able to integrate information across sentences, comprehend the same information from different input sources, understand more about familiar topics, make inferences, translate texts, take perspectives, remember information, update knowledge, and learn from reading texts. Considering that a number of cognitive processes such as lexical processes (involved in accessing word meanings), memory retrieval (to elaborate on the text), incorporating prior knowledge, inference processes (to help assimilate the meaning of previously read sentences with the current sentence), and learning processes are involved in the construction of situation models, it follows

that such a model provides the reader with a representation that is more than an image of the text (Zwaan & Radvansky, 1998). In other words, creating a situation model allows the reader to form a ‘mental’ picture that captures more than the meaning of individual words and sentences, and represents the unique ‘situation’ described in those sentences. Take, for example, the following text (Zwaan & Radvansky, 1998)

> *Lamar Alexander was behind in the polls. However, the former Tennessee governor remained optimistic. He considered it likely that a moderate candidate with new ideas would win the Republican nomination.*

The text base analysis would tell the reader that 'Lamar', 'the former governor of Tennessee', 'he', and 'moderate candidate' all refer to the same entity as informed by use of proper noun, definite article 'the' and pronoun ‘he’. Even when the reader has no prior knowledge of *Lamar Alexander* or any domain knowledge regarding American politics, they can infer that the person by the name of *Lamar Alexander* was a governor of *Tennessee* who ran for the Republican Party nomination and referred to himself as ‘a moderate candidate with new ideas’. All the information that was presented in the text and inferences generated by the reader are represented in the situation model. Thus, situation models are ‘coherent’ representations of what the text is about. Their creation involves integrating information derived from grammatical, world, and domain knowledge.

Cognitive Models of Situation Model Construction

A widely accepted view in cognitive psychology is that in order to comprehend a text, the text needs to be represented in a coherent manner in memory, and undergo processes such as making causal connections, drawing inferences and using background knowledge to link propositions together (van Dijk & Kintsch, 1983). A number of models offer theoretical frameworks to explain situation model

construction. These include the ‘interactive model of comprehension’ (Kintsch & van Dijk, 1978); the ‘construction-integration model’ (Kintsch, 1988); the ‘structure-building model’ (Gernsbacher, 1990); the ‘event-indexing model’ (Zwaan, Langston, & Graesser 1995a; Zwaan & Radvansky, 1998); the ‘capacity-constrained construction-integration model’ (Goldman, Varma, & Cote, 1996) ; the ‘experiential-simulations approach’ (Zwaan, 2008). Though all of these frameworks attempt to conceptualise situation model construction, the construction-integration model by Kintsch (1988; 1998) and the event-indexing model by Zwaan, Langston, and Graesser (1995a) are the most influential.

Before discussing the details of any of these models, it would be useful to determine what are the expectations from these models? They should be able to answer core questions regarding the nature of situation models such as, how are situation models constructed? What are the processes involved? What information is represented in a situation model? How are situation models updated? How are these representations stored? How are they retrieved from memory?

Construction-Integration Model

The construction-integration (CI) model (Kintsch, 1988; 1998) attempts to explain how knowledge is activated and integrated into representation of the text in memory. The key supposition here is that text comprehension involves forming propositions. Kintsch defines propositions as a ‘statement making a claim’. The ‘*construction’* part is turning a sentence into propositions. These propositions represent the meaning of the text and are buffered into short-term memory buffer to form a *propositional net*. Each proposition in the buffer also retrieves other associatively related propositions from long-term memory. At this stage, contextual information is not used to limit the number of propositions being included, resulting

in a bottom-up approach. The '*integration*' part describes how knowledge stored in the long term memory is integrated into the current text propositions to form an *elaborated propositional net*. The propositions that are highly interconnected attract most activation and are likely to be included in the representation of the text. The resulting multilevel representation of the text itself (surface representation), its propositions (text base), and situational representation (situation model) is stored in the episodic text memory as an amalgamated structure with no distinction between propositions based directly on the text or previous background knowledge.

The construction-integration model provides some insight into the nature of situation models including the level of meaning represented at situational level being stored in long-term memory (Kintsch, 1992), the contribution of prior knowledge in constructing situation models (Callies, Denhiere, & Kintsch, 2002), and the extent that the goal of the reader influences the type of representation formed (Kaakinen & Hyönä, 2007). However, the model does not fully accommodate the flexible nature of text processing, and the influence of context in limiting irrelevant propositions at early stages of processing (Cook & Myers, 2004). Though this model gives a good account of reading comprehension processes overall, it does not specify the processes involved in construction of situation models and the types of information represented in situation models.

Event-Indexing Model

The event-indexing model by Zwaan, Langston, and Graesser (1995) and updated by Zwaan and Radvansky (1998) provides a theoretical framework that describes the processes involves in construction and storage of situation models along with the content represented at the situation model level.

According to the event-indexing model, as readers read through text, they

extract intentional 'events' from the text and integrate the representation of each event into a richly connected and coherent representation. These 'events' form the focal points of the situation models. While processing an event, the reader indexes the information along five different dimensions or indices (Zwaan, Magliano, & Graesser, 1995b). Each event is indexed on the time frame (order, duration) and spatial (location) region in which it occurs, the protagonist/s (entities, objects) it involves, intentions (goals and motivations) of the protagonist/s and the causal relations between current and previous events.

As new events are processed, information is integrated into the current model along any or all of the indices. The more indices a new event shares with previous events, the easier it is to incorporate it and '*update*' the model, resulting in the '*integrated*' situation model. The event-indexing model views updating as 'here and now' (Zwaan & Madden, 2004). This view predicts that the most recent information and representation would be more readily accessible than outdated information. This model assumes that all the five dimensions are monitored independently of each other and takes into account the cognitive effort involved in accommodating discontinuity along any of the dimensions compared to when they remain the same.

General processing framework. The event-indexing model proposes that situation models are constructed within a *general processing framework* and proposes two general hypotheses about processing and representation (Zwaan & Radvansky, 1998). The *processing load hypothesis* concerns the *updating* process and states that the ease of integrating the current event into the evolving situation model is directly proportional to the number of indices shared between the current and previous event. The *memory organisation hypothesis* concerns the representation of the complete model in long term memory and states that the number of

dimensional indices shared between events is directly related to the strength of their association in memory. In other words, the more indices shared between events, the stronger the association of those events in memory. Thus, according to the event-indexing model, both the number of events that are connected to each other and the number of dimensions on which those events are connected affects the ease of integrating the events, updating the situation model, and representing the model in memory.

Within Zwaan and Radvansky's (1998) general processing framework, creation of the final representation of the text in long term memory involves progressive stages or creating different types of situation models. The '*current model*' is the model currently under construction at time t_n as the reader reads a particular clause or sentence c_n. The *'integrated model*' is the model that has been arrived at by integrating the models constructed through times t_1 to time t_{n-1} as the reader continues reading and arrives at clause/sentence c_{n-1}. As each clause is read, its representation is integrated into the model created thus far in time. This process of incorporating the current model into the integrated model is called '*updating*'. The '*complete model'* is the model that includes the integrated model and the current model of the last clause read. This complete situation model is stored in long-term memory and is available for retrieval as required. It is, however, not the final model as the reader is able to retrieve the model and add new inferences to it or refine it further. It is merely the completed mental model of the set of clauses or events processed before the representation is stored in long-term memory.

Within the event-indexing framework, situation models are conceptualised as evolving models where the current model becomes the integrated model as soon as the next event is processed. Along the different dimensions, each subsequent event is

integrated with the previous one until all the textual input has been processed. As soon as information along a dimension becomes available, it is included in the evolving situation model. In other words, the process of creating a situation model is not sequential with the reader systematically going through the different dimensions. Rather this is conceptualised as occurring simultaneously or in parallel. Taking an example text as discussed by Zwaan and Radvansky (1998):

> *Peter took the elevator to the fifth floor. He went to talk to his professor. He was anxious to find out how the professor liked his draft. He walked up to the professor's office and knocked on the door. The professor looked up from his work.*

As the first sentence is processed, the reader constructs the current situation model at time t_1 that includes a token for the protagonist, Peter, and his spatial location, the elevator. Hence the first sentence was indexed on two aspects or dimensions- protagonist (Peter), spatial (elevator). As soon as the second sentence is read, its model constructed at t_2 becomes the current model and the model at t_1 becomes the integrated model with the second sentence being integrated with the first on several dimensions. The pronoun 'he' refers back to the protagonist identified in the previous sentence and is integrated with ease on that dimension. The words 'went to' create the intentionality or goal dimension. The continuation of the current activation of an event node is the default mechanism in comprehension (Zwaan et al., 1995a). Therefore, if no additional information along a dimension is available then the last available information node is brought forward to the integrated model. In this example text, as there is no new temporal information or spatial marker in the second sentence, the nodes established in long term working memory along the temporal and spatial dimensions are kept active. The last word of the sentence 'professor' cues the creation of a new token. At the same time, the context of the

protagonist Peter, and a goal directed towards the new entity *Professor* leads to the inference that *Peter* is in fact a student. This inference forms part of the content of the model at t_2. The model constructed at t_1 is updated by incorporating the model t_2 into it. Each new sentence would lead to creation of the current model and its assimilation into the integrated model leading to the integrated model reflecting the meaning created so far. Therefore, comprehension within this framework is a cumulative process where information from each successive sentence or event, and inferences generated based on such informations, collectively add to the representation of meaning stored in memory.

Relevance and retrieval. Relevance is a 'key' notion in the conceptualisation of situation models (Zwaan & Radvansky, 1998). Situation models are updated by forming connections between the current model and 'relevant' aspects of the integrated model along the different indexes or dimensions. Zwaan and Radvansky (1998) use the concept of '*foregrounding*' to explain what constitutes relevant information. Information is considered to be foregrounded if the reader creates and maintains a retrieval cue for that information in short term working memory (STWM) buffers to parts of the integrated model in the long term working memory (LTWM). Put simply, foregrounding allows readers to select what information to keep active in memory in order to include it in the situation model. Not all the information explicitly mentioned in the text or inferred from the text and own knowledge can be included in a situation model. Readers can foreground information based on linguistic cues, world knowledge, and knowledge about narrative genre or on the basis of explicit focus. The use of linguistic elements such as definite versus indefinite article, proper nouns versus role names among others act as cataphoric devices, referring to specific bits of information (such as 'the or this man') and

prompt the reader to foreground information and create a retrieval cue for it.

The concept of 'retrieval' refers to the process of bringing parts of the integrated or final model from long-term memory to LTWM and STWM. The current model is constructed in STWM whereas the updating of the integrated model occurs across the STWM and LTWM, and parts of the integrated model and complete model are stored in long-term memory (Zwaan & Radvansky, 1998). Only the elements of the model that contain the 'highlighted' or foregrounded information retain a retrieval cue in STWM. As the reader progresses further through the text and new events are processed, the retrieval cues (created by the foregrounded information) in STWM allow the integrated model to be updated by bringing parts of the integrated or final model from long-term memory into short-term memory for elaboration. Referring again to the example of Peter,

> *Peter took the elevator to the fifth floor. He went to talk to his professor. He was anxious to find out how the professor liked his draft. He walked up to the professor's office and knocked on the door. The professor looked up from his work.*

In this text, *Peter* is introduced by proper name, and a retrieval cue for his character is created in STWM. As Peter is the explicit focus of this text, he is in the foreground of the story whereas, the *professor* by being introduced with a role name is consigned to the background. Thus the process of foregrounding helps the reader to maintain relevant aspects of the integrated model in the LTWM, while processing the current model in STWM.

Different dimensions may have different criteria for what constitutes relevant parts of an integrated model. Spatial information associated with the protagonist is more likely to be foregrounded in the situation model (Glenberg, Meyer, & Lindem, 1987). Use of causal connectives such as 'because', 'so', 'therefore', and

'consequently' foregrounds causal information and statements of a goal foreground intentionality (Lutz & Radvansky, 1997). Protagonists and objects tether situation models and use of proper names and anaphoric reference foregrounds information along the protagonist dimension (Gordon, Grosz, & Gilliom, 1993). Use of temporal markers and connectives makes temporal relations explicit and foregrounds them (Zwaan & Radvansky, 1998). Continuing with the example of Peter, *Peter* is more likely to retain a retrieval cue in STWM than the *professor* even though both are part of the integrated model. The intentional dimension would retain its retrieval cue until Peter's goal of finding out the professor's opinion about his draft is satisfied. The spatial dimension would retain a retrieval cue of Peter's location on the fifth floor office. The action of Peter knocking and the professor looking up would be the foregrounded information along the causal dimension maintaining a retrieval cue in STWM.

The advantages of the event-indexing model lies in its ability to describe the processes involved in creating and updating situation models. It describes the different stages of processing involved in creating situational understanding. It details the different dimensions represented in situation models, and the process of updating the models. The event-indexing model explains how we store and retrieve situation models from memory. The main criticism of the model stems from its view that all five dimensions are equal and independent of each other. This view was based upon the lack of correlations between dimensions in the initial study of the event-indexing model by Zwaan et al. (1995a). However, Therriault and Rinck (2007) highlight the impact of significant correlations between dimensions and provide an alternate interpretation for the results from existing studies (e.g., Zwaan et al., 1995a; Zwaan et al., 1995b; Rinck, Hahnel, & Becker, 2001; Rinck & Webber,

2003; Therriault, Rinck, & Zwaan, 2006). They argue that statistical correlations and interactions between dimensions suggest varying dimensional dominance with protagonist and temporal dimensions being critical to situation model construction while spatial, intentionality and causality dimensions appear to be second-order dimensions. Another criticism of the event-indexing model is its general claim that a situation model is always updated to accommodate new information with no explanation for exceptions such as difficulty in updating protagonist character information in instances where the original assumption was incorrect (e.g., Rapp & Kendeou, 2007; van der Schoot, Horsley, & van Lieshout, 2010). The event-indexing model also does not discuss internal representations of events formed during language comprehension.

Experiential-Simulations Approach

Zwaan (2008) proposed the experiential-simulations approach as a more specific and complementary approach to the event-indexing model. This approach assumes that comprehension is anchored in the creation of situation models that are more perceptual in nature and are similar to the representations created if the individual would have actually experienced or re-experienced the situation (Kaup, Yaxley, Madden, Zwaan, & Ludtke, 2007). It treats situation models as sort of 'mental simulation' of the described affairs and predicts that the representations would hold details that would be present as if the described situation was actually perceived (Zwaan, Stanfield, & Yaxley, 2002). Support for the experiential-simulations approach stems from reaction time findings where participants were faster to recognise the shape of an object in a picture when it matched the description implied by the sentence (Zwaan et al., 2002). This points towards the creation of a perceptual simulation or specific mental visualisation of the situation described in

the sentence (Kaup et al., 2007).

While the experiential-simulations approach with its assumption that the perceptual simulation formed is the only meaningful representation created for comprehension appears to be more economical than the multi-levels of representations formed in the construction-integration model, the construction of such rich perceptual mental simulations appears cognitively taxing and demanding. Therefore, it could follow that readers create experiential-simulations in certain circumstances. However, these specific conditions and circumstances are not yet defined in the approach. Another issue to address within this approach is comprehension of abstract materials. The questions that needs to be answered is how would one create a perceptual simulation of a situation that has never been experienced?

Summary of Cognitive Models of Situation Model Construction

In summary of these major theoretical frameworks of situation models, while the construction-integration model conceptualises situation models as being dynamic, it is not specific about the processes that guide their construction or the aspects of the situation represented in it. The event-indexing model extends on this conceptualisation and describes the processes involved in constructing situation models. It provides a framework to examine how readers monitor, update, and integrate information along different dimensions to create situation models that reflect the described events. It predicts the negative impact of increasing processing load and the enhancing effects of generating inference and previous knowledge on comprehension. The experiential-simulation approach can be thought as describing the quality of mental representations formed during comprehension resulting in situation models similar to actual perceptual experiences of the described situation.

The construction-integration model and event-indexing model are complementary with each providing a description of a part of the comprehension process. The construction-integration model describes general text comprehension processes and representations, while event-indexing model describes higher-order text representations, namely, situational models in more detail. As the focus of this literature review is situation models, the event-indexing model is the framework used to review the evidence for the different facets of situation models.

Research on Situation Models

The concept of situation models has been researched since the 1970's even before the term came into wider use. Prior to that, research on comprehension largely focussed on 'propositions' (van Dijk and Kintsch, 1983). The first influential study of situation models was by Bransford, Barclay, and Franks (1972). Their 'three turtles experiment' investigating the spatial dimension laid the foundation of situation model research. The premise of their experiment and its findings was that if listeners create a representation of the described situation then they are likely to false alarm to a sentence that describes the same situation (and therefore would lead to the same mental representation) even if it is coded linguistically differently. They presented sentences such as 1a and 2a to participants and later presented sentences such as 1b and 2b in a recognition test.

1a. Three turtles rested *on* a floating log, and a fish swam beneath *them*.

1b. Three turtles rested *on* a floating log, and a fish swam beneath *it*.

2a. Three turtles rested *beside* a floating log, and a fish swam beneath *them*.

2b. Three turtles rested *beside* a floating log, and a fish swam beneath *it*.

Using a sentence recognition *memory task* as measure of situation model creation, Bransford et al., found that participants falsely recognised new sentences (1b) as

ones that had previously heard (1a) if the new sentence described the same situation. However, in the case of sentence set 2a and 2b, participants were less likely to false alarm as even though the sentences are similar at the propositional level, they describe different or unique situations. With the test sentences and new sentences being minimally different on the surface level and similar on the propositional level, any differences could then be attributed to the third level of representation, the situation model. This was taken as evidence that situation model level of representation is created and stored in long term memory.

The last four decades of research on situation models has sought to answer some key questions regarding situation models including: What dimensions (types of informations) are represented in situation models? Is monitoring (information along different dimensions) automatic? Are the different dimension independent? However, there is no general consensus with regard to what comprises a situation model and the types of information it might represent (Glenberg et al., 1987; Therriault & Rinck, 2007). These issues relate to the very nature of situation models, namely, their multidimensionality; the variety of experimental tasks and measures employed to study them; inconsistent findings along similar experiments; and the interpretation of results.

Tasks and Measures used in Situation Model Research

Situation models are referential representations that encapsulate understanding of the described circumstances (Radvansky & Copeland, 2010). This requires two assumptions in empirical testing of situation models. The first being that the experimental tasks or texts used to elicit a situation model do in fact lead the participant to create a situation model and secondly, that the measures employed actually measure some aspect of situation models. It is important to keep these

assumptions in mind while discussing results from situation models considering that text characteristics, and test measures can have significant effects on findings. The measures used in situation model research have undergone a change through the years.

Offline tasks. The research in the early 1970's and 1980's primarily used offline measures which examine meaning representations established after comprehension is completed. As discussed earlier, Bransford et al. (1972) used a memory recognition task which required participants to create and store mental representations of sentences, and use those representations to make later recognition decisions. Other offline tasks include memory probes, recall protocols, answering questions, old/new recognition judgements, true/false verification judgements, and importance ratings (Graesser, Millis, & Zwaan, 1997). These measures provide evidence of whether a mental representation has been constructed, and examine the finished product, i.e., the representation of the complete model in long term memory, and the retrieval of the whole or parts of it.

Conceptual and methodological issues concerning such off-line tasks are illustrated by consideration of the probe-word recognition task, in which a participant reads or hears a sentence with a probe word being presented at a predetermined point after the sentence has been read. The participant is required to make a rapid judgement as to whether or not the probe word has occurred in the sentence. The response time to the probe is used to make inferences about the representation of the sentence in memory via accessibility of concepts (Gordon, Hendrick & Foster, 2000). However, it is possible that response times in probe-word recognition tasks could be influenced by strategies aimed at keeping track of the words. Gordon et al. (2000) found that such recognition tasks could induce

participants to create representations that were more conducive to memory experiments and were dependent on the types of list and probe words used. If the purpose of studying situation models is to examine the processes, and representations that are constructed during comprehension, such offline measures are inappropriate.

Online tasks. The use of measures reflecting online processing has not been as widespread as would be expected considering that research on reading comprehension is motivated by a desire to examine the processes involved in creating, updating, and retrieving situation models (Kinnunen & Vauras, 2010). Reading times and lately, eye tracking measures have increased in prominence in research on situation models (van der Schoot et al., 2010; Rinck et al., 2001; Rinck, Gamez, Diaz, & de Vega, 2003). These measures provide indications of ease or difficulty of text processing and shed some light on the processes that underlie the incremental integration of words and phrases into sentence representations (Witzel, Witsel & Forster, 2012).

A common reading time task used in research on situation models has been the self-paced reading (SPR) moving window task (Just, Carpenter, & Woolley, 1982). In this task, each text segment (word, clause, sentence or even paragraph) is represented by a series of dummy characters (e.g., hashes) with only the text segment currently being read being visible at any time and the rest of the text being dummy characters. The dependent measure in the SPR moving window task is the total reading time, which is expected to be longer for sentences that cause comprehension breakdown due to the reader slowing down to resolve the breakdown or attempting to retrieve information from memory (Witzel et al., 2012; Rayner et al., 2006; Rinck et al., 2003). While SPR moving window task forces adoption of the same reading

strategy across subjects and items, presenting texts segment by segment with only one segment available at a time is not reflective of natural reading processes (Kinnunen & Vauras, 2012; Rayner et al., 2006). The bigger concern with the self-paced reading moving window task is that it does not allow for look-backs or re-readings to resolve comprehension difficulties, thus losing valuable information on cognitive strategies (Rayner et al., 2006) and might over emphasise the importance of memory on reading comprehension (Witzel et al., 2012). Overall, though reading times reflect online comprehension processing, they can sometimes be ambiguous in regard to the contents and the processes they are assumed to index (Graesser et al., 1997).

Radvansky and Copeland (2010) raise a note of caution regarding the interpretation of reading times and state that, although finding a difference in reading time is indicative of updating difficulty, a lack of reading time difference doesn't automatically and necessarily mean that updating is not occurring. They propose gathering cumulative evidence for comprehension difficulty (or lack of) by way of additional measures such as memory probes in addition to standard reading time measures. However, metacognitive tasks such as memory probes, word recognition (which require the reader to make a decision whether a target word has occurred in the text), and think-aloud tasks (where readers report their thoughts while reading) require the reader to be periodically interrupted during reading for data collection. So despite providing information about possible comprehension strategies being used as the text is comprehended, use of these aforementioned measures can potentially result in the reader constructing shallow, choppy representation (Graesser et al., 1997).

Recently, researchers have started examining discourse comprehension using

fMRI and EEG neuroimaging techniques (Yarkoni, Speer, & Zacks, 2008). These studies have examined brain areas involved in coherence building (Ferstl, Neumann, Bogler, & von Cramon, 2008; Moss, Schunn, Schneider, McNamara, & van Lehn, 2011), construction and maintenance of situation models (Yarkoni et al., 2008), and cerebral correlates of narrative shifts (Whitney et al., 2009). While the focus of these studies has been identifying brain areas involved in text processing, they have not yet begun untangling the dynamic interaction of cognitive processes and strategies involved in creating and updating complex situation models (Moss et al., 2011).

Eye tracking provides another on-line measure of processing difficulty with high temporal resolution, without relying on any secondary task to produce the dependent measures. Eye movement paradigms measure the participant's gaze on the material being read. Reading comprehension and regulation strategies can be illuminated by considering measures of change in speed, fixation paths, gaze durations and re-readings as reflecting ease or difficulty in updating mental representations (Kinnunen & Vauras, 2012). The advantages of this method are that it allows for natural reading processes without imposing constraints on the strategies employed (Rinck et al., 2003; Kinnunen & Vauras, 2012). However, it is not yet fully understood how the different commonly used dependent measures (e.g., first fixation time, probability of a regression) are linked to specific cognitive events (Witzel et al., 2012).

Experimental manipulations. Research on situation models have utilised texts ranging from single experimenter constructed sentences (Bransford et al., 1972; Rinck et al., 2001; Zwaan, 1996; Rinck & Weber, 2003) to long naturally existing texts (Zwaan et al., 1995; van der Schoot et al., 2010). Findings show that both single sentences and longer narratives lead to construction of situation models. The

experimental manipulations of texts are based on the processing load hypothesis of the event-indexing model which predicts that the fewer situational indices shared between the currently processed event and the current situation model, the harder the situation is to process. Self-paced reading moving window and eye tracking studies have primarily utilised two paradigms. In the *inconsistency paradigm* (Albrecht & O'Brien, 1995; Rinck et al., 2001), comprehension is expected to slow down if new information is inconsistent with information provided previously along any dimension, while in the *discontinuity paradigm* (Zwaan et al., 1995b; Zwaan, Radvansky, Hilliard, & Curiel, 1998; Therriault et al., 2006), comprehension is expected to slow down when discontinuity is encountered along any dimension. These two paradigms examine different aspects of situation model updating with the focus of the inconsistency paradigm being monitoring of content and overall meaning of the text, while the discontinuity paradigm focuses on monitoring for continuity along the dimensions. Difficulty in updating the situation model could be indexed by an increase in reading time, regression back to previously read sentence or earlier in the sentence, and re-reading sentences (Rinck et al., 2001; Rinck et al., 2003; Therriault & Raney, 2007; van der Schoot, Reijntjes, & van Lieshout, 2012).

Often in situation model research, the dimension of interest is highlighted in the text (Therriault et al., 2006). Graesser, Kassler, Kreuz, and McLain-Allen (1998) discuss this issue stating that readers are often directed towards particular dimensions by the instructions provided, materials used, or experimental tasks. This inadvertent focussing of readers on the test dimension could be via explicit instruction to memorise as in the study by Morrow, Bower, and Greenspan (1989). Participants were asked to memorise a spatial layout and then accessibility of object locations was probed during reading. The results of this study were interpreted as

evidence for representation of spatial information in situation models. However, it is possible that memory instruction could have engendered special strategies in the reader that might not have been engaged normally (Zwaan et al., 1995b). Pushing the reader knowingly or unknowingly to engage strategies that they normally would not have used detracts from the validity of research findings and claims.

Rinck and Weber (2003) provide guidelines for constructing experimental texts and identify two critical features. The first being that the text should allow for full combination of all the shifts investigated, comprising all combinations from no shift at all to simultaneous shifts on all dimensions. Secondly, the text should allow for complete counterbalancing of materials and experimental conditions. They further advise using identical target sentence in all experimental conditions. This level of experimental control is sensible considering the use of regression analysis to determine the effects of situational shifts. The authors further caution against drawing strong causal conclusions, testing potential interactions between dimensions, and comparing relative effect sizes of different dimensions using a regression approach owing to its correlational nature. The key notion here is ensuring that the experimental texts appear plausible and readable so as to simulate the natural reading process as much as possible while still maintaining experimenter control. However, these recommendations do not address the issue of equating multiple dimensions in a text. Therriault et al. (2006) advocate focusing the readers' attention on a particular dimension while studying situation model updating for another dimension as a way of circumventing the issue of trying to equate and control the various dimensions within the experimental design. As this is a conservative design, it is unlikely to overestimate the contribution of the non-highlighted dimensions. Most importantly, explicitly focussing the readers' attention

on a particular dimension while also measuring the non-highlighted dimensions provides some insight regarding the importance of those dimensions.

Inconsistencies in Situation Model Findings

Even though all the dimensions are thought to be crucial, different dimensions have attracted varying amounts of researcher interest. Findings relating to the temporal and causal dimensions are quite consistent, with various studies (such as Zwaan, 1996; Rinck & Weber, 2003; Therriault & Raney, 2007; Radvansky & Copeland, 2010) finding that these dimensions are routinely monitored.

The spatial dimension has been most heavily studied. By creating a mismatch between spatial organisation and linguistic structure, researchers can easily study whether a text base or situational level of representation is being created. Put another way, the multidimensional structure of space and the linear nature of language provide the opportunity to create a mismatch, which can be exploited to explore situation models. Findings for the spatial dimension are less clear-cut than for other dimensions (Zwaan & Radvansky, 1998). Some studies found support for spatial information being represented in situation models (Bransford et al.,1972; Morrow et al., 1987; Haenggi, Kintsch & Gernsbacher, 1995) and others found partial evidence (Jahn, 2004). However, other studies failed to find clear evidence for spatial information being represented in situation models (Zwaan et al., 1995b; Zwaan & van Oostendorp, 1993).

In the first group of studies, the experimental tasks placed explicit focus on spatial information and encouraged participants to pay attention to spatial information. This raises the possibility that these findings might not generalise to different texts and genres. For example, in a replication of the Bransford et al. ‘three turtles’ experiment, Jahn (2004) found that spatial location and relations between

entities were monitored in conditions where that information was causally relevant. The author constructed stimuli, based on the sentences used by Bransford et al., depicting peaceful scene (no causal relevance) and predator scene (causal relevance) and found that there was more erroneous recognition of new same-model sentences as old, and better correct recognition of new different-model sentences as new for predator scenes only. This finding of better discriminability of different-model sentences than same-model sentences for causally relevant scenes suggests that causal relevance plays an important role in spontaneous spatial representations in text comprehension. Thus, it could be that readers monitor spatial information when they deem it relevant for establishing a causal link.

Morrow et al. (1989) required participants to memorise the layout of a building and then read a narrative that described the protagonists' goal directed movements through the building. The dependent variable was a memory probe of object locations where the participants indicated whether the probe objects belonged in the same or different rooms of the building. While the protagonist's current location influenced the accessibility of objects, the protagonist's goal exerted an even stronger influence. Participants focused on the protagonist's goal, and objects associated with the fulfilment of that goal were more accessible regardless of whether they had been mentioned in the narrative. Thus, their finding that spatial information is represented and monitored needs to be qualified with the addition that relevance to protagonist goals could be a precondition for monitoring spatial information in some cases. In contrast to aforementioned findings, O'Brien and Albrecht (1992) found that some spatial information was encoded even when the task did not require it. The participants read passages in which an inconsistency concerning the protagonist's location was presented. The authors found that

participants monitored information concerning the protagonist location and that when this information was violated, there was an increase in reading times. Thus, under relatively natural reading conditions, compared to the explicit memorising of building layout in the Morrow et al. study, readers were found to represent, at the minimum, some spatial information in their situation models. Instead of viewing these findings as inconsistent, a further analysis of the texts and tasks used might provide clues. In the O'Brien and Albrecht study, the subjects focused on information that was relevant to the protagonist and monitored spatial information deemed important for the protagonist.

The issue with research on different dimensions of situation models yielding seemingly different results is not so much a case of incompatible results as a case of needing to qualify the results with the preconditions where particular information is likely to be included in the mental representation of the event. It could be that text genre and reader motivation affects both the types of representations created during comprehension, and the content of those representations. Radvansky, Zwaan, Curiel and Copeland (2001) propose that readers approach narrative texts with the intention of understanding the events and their relation to each other while expository texts are read for the purpose of understanding the content. This would then influence the dimensions deemed important and necessary to fulfil the reader's goal. It is likely that the reader would focus on the protagonist, emotions, motivations and actions for the narrative genre and causal relations for the expository genre. Thus, it might be more prudent to shift the focus of research on situation models from whether or not a particular dimension is represented in situation models to a focus on specifying the preconditions where it would be beneficial to represent it in order to fully comprehend the text. Levine and Klin (2001) articulate this concern stating that the

amount of information that can be included in a situation model is limited, so an examination of what influences a reader to include or not include certain information might be more fruitful. The importance of the clues that make certain information more salient ties in with the concept of foregrounding from the event-indexing model of situation model construction.

Complex Relationships between Multi-dimensional Situation Models

The above discussion highlights the importance of interactions between different dimensions in situation models. Researchers in the field of comprehension and memory have traditionally investigated individual dimensions separately without due controls for the effect of other dimensions (Zwaan & Radvansky, 1998). Even though single dimension studies have increased our understanding of the specifics of each dimension, they do not provide information about the necessity of each dimension and the effects of interaction between dimensions during situation model construction (Therriault et al., 2006). The issue of whether or not a dimension is automatically and spontaneously monitored during situation model building is key as it implies that that dimension is critical in the construction of situation models.

Temporality, spatiality, and causality are inextricably linked in how we experience the real world (Zwaan et al., 1995b). In the Bransford et al. (1972) study, the authors examined a single dimension, spatial, and claimed that spatial information is included in a situation model. A replication study done by Jahn (2004) found that readers did in fact represent spatial information in situation models but only in conditions where location was causally relevant. In other words, causal dimension influences spatial relations, and whether that information is subsequently included in the situation model.

The often cited study by Linde and Labov (1975) can be used to illustrate the

inter-relatedness of dimensions. In this study, participants were asked to describe their apartment. The authors found that participants reported the layout of three dimensional space sequentially, forcing spatial information into a temporal order format. Similarly, Lutz and Radvansky (1997) probed participants for information from a story, and found that completed goal information was still more accessible than incoming neutral information. These examples illustrate that even though the different dimensions are separate, they are not independent from each other, and any examination of a dimension should control or at least acknowledge the effects of other dimensions.

However, the difficulty with multi-dimensional research lies in equating information across dimensions. There is no metric to equate inconsistencies or discontinuities across dimensions. Keeping these concerns in mind, more recent studies have focused on multiple dimensions while varying the information systematically across dimensions. In one such multi-dimensional study, Therriault et al. (2006) empirically examined whether spatial, temporal and protagonist dimensions were monitored spontaneously during reading comprehension. They systematically manipulated the readers' focus along each of the dimensions with explicit instruction to focus on a predetermined dimension (highlighted dimension) of the text. All three dimensions contained shifts but the readers' attention was directed towards the highlighted dimension. Taking reading time data as measure of ease or difficulty of updating the situation model, they found an increase in reading times for shift-sentences for temporal and protagonist dimensions even when the reader was explicitly asked to pay attention to another dimension, while the spatial dimension was monitored only when explicitly instructed. The authors interpret these findings as evidence for temporal and protagonist dimensions being a critical

component of a coherent situation model. Keeping the notion of inter-dimensional influence in mind, findings of Therriault et al. can be reconciled with previous findings on spatial dimension (e.g., Bransford et al., 1972; Glenberg et al., 1987) as specifying the conditions where monitoring spatial dimension becomes obligatory.

Rinck and Weber (2003) investigated the effects of protagonist, temporal, and spatial shifts on situation models by systematically varying the shift along dimensions while instructing the participants to read for comprehension. The authors measured sentence reading times and found an interaction between the spatial and protagonist dimensions. This led the authors to propose that plausibility and frequency of dimensional combinations could influence the increase in processing load. In other words, if an event involves a highly plausible shift, such as the protagonist making a location shift that is keeping in line with the goal, then it is less likely to cause an increase in processing load.

Thus, the findings on situation models seem to suggest that all the currently known dimensions (temporal, protagonist, spatial, intentionality, and causality) can be represented in a situation model. However, this representation is mediated by reader's goals, and the interactions between the dimensions. Therriault and Rinck (2007) make the case that temporal and protagonist dimensions are first-order dimensions while the causal dimension can be thought of as a sub-component of the temporal dimension, and intentionality is subservient to the protagonist dimension. These claim are plausible considering a causal chain of events is interlinked through time. In order to establish intentions or goal, it is important to establish the protagonist, and the spatial-temporal zone that the protagonist exists in. It could be that the protagonist forms the core of a situation model, while intentional and possibly emotional information is indexed upon that core. Evidence from different

genres of texts needs to be collected to further the understanding of the representational contents of a situation model.

Summary and Future Directions

In summary, comprehension involves the construction of a mental representation of the text, referred to as a situation model (Kintsch, 1998; Zwaan & Radvansky, 1998). The reader constructs a representation of the content described in the text that abstracts away from the wording of the text and generates a fuller understanding of the text by including inferences, and own knowledge. Within the event-indexing theory framework, key processes relate to construction, updating, and retrieval of situation models, and the ease or difficulty of integrating new information into the evolving situation model is dependent on the number of indices shared along the different dimensions. Situation models are typically deemed useful to explain issues of coherence, perspective taking, translation, updating knowledge, and learning from multiple sources (van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998) but they can also be a useful framework to study individual differences in comprehension abilities (van der Schoot et al., 2010). Relevant online comprehension processing tasks such as reading times, eye tracking, and neuroimaging techniques should be used to study comprehension processes, and points of breakdown by examining the processes involved in construction of a rich coherent situation model, and/or updating of the mental representation (van der Schoot et al., 2012).

Situation models provide a useful framework for understanding comprehension processes in developmental and acquired disorders of cognition. Poor comprehension skills are seen in individuals with specific comprehension difficulties (poor comprehenders), autism spectrum disorders, and language impairments among

others. The questions that could be answered using the situation model framework include whether individuals with different clinical profiles are impaired in their ability to construct and update situation models, monitor comprehension along the relevant dimensions, foreground information, or detect inconsistencies. The results from such studies could inform intervention programs where individuals are taught explicit strategies to select relevant information, create inferences, or read with specific goals of monitoring particular types of dimensional markers (for example, causality markers, temporal markers) in order to improve reading comprehension.

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Abstract

Situation models are integrated mental representations of the events described in a text. Previous studies examining situation models have relied on either reading times with only the current sentence being visible, or eye tracking of the whole text. In an experiment, participants read short texts containing temporal information while reading times and eye movements were recorded. The texts were presented sentence-by sentence via key-press, and the sentences stayed on screen until the entire text was visible (cumulative presentation). Such a combined methodology was expected to provide complementary information regarding the cognitive processes involved in comprehension. In the *Discontinuity effects manipulation*, participants read texts describing either contiguous events or the same events separated by a temporal shift. Reading times for shift target sentences were increased but eye movement analyses did not offer any novel insight. In the *Inconsistency effects manipulation*, participants read texts containing a target sentence that was either consistent or inconsistent with critical temporal information in an earlier sentence. Reading times for inconsistent sentences were increased and eye movement analyses showed increased total fixation (gaze) duration on target sentence and the earlier sentence containing critical temporal information, as well as more direct regressions from target to critical temporal information sentence. Methodological implications of the results for future research are discussed. Clinical applications of utilising situation model framework to study cognitive processes involved in reading comprehension are offered. Situation models can be useful in studying individual comprehension differences, and the processes involved in comprehension monitoring.

Temporal Information in Texts: An Experimental Study combining Reading Times and Eye Movement Measures

Text comprehension is more than the product of recognizing and understanding individual words and phrases (Cain & Oakhill, 2006). Reading comprehension research generally assumes that text representation involves multiple levels with processing at the *surface*, *text base* and *situational* level (van Dijk & Kintsch, 1983; Kintsch, 1998; Zwaan & Radvansky, 1998). The *surface* or linguistic processing relates to processing of words and phrases contained in the text itself and includes processes such as decoding, word recognition, and assigning thematic roles. The next level of text comprehension is the *text base* level. This relates to semantic analysis of the text and represents the meaning expressed in the text itself. Text base processes include forming propositions, identifying co-reference, building bridging inferences, and recognising and organising interrelationships and themes. However, if the reader wishes to go beyond the meaning expressed explicitly by the text, 'higher level' processing is required. This level of processing allows the reader to integrate the information provided by the text with relevant prior knowledge, inferences, and goals of the reader to create a rich mental representation of the events described by the text, called a '*situation model*' (Kintsch, 1988; 1998; Kintsch & Rawson, 2005; Zwaan & Radvansky, 1998).

During reading, the surface form and text base representation are steadily lost from memory, whereas the memorial representation of the situation model level remains fairly stable (Radvansky, Zwaan, Curiel & Copeland, 2001). This retention of situation model knowledge in memory creates our background knowledge that can be used to generate inferences, and linked to a subsequent situation model constructed at a later time. Without these processes of generating inferences, and

activating prior knowledge and experience, textual information cannot be linked up with existing knowledge structures remaining as inert, unusable information (Kintsch & Rawson, 2005). Thus, situation models are dynamic and interact with information from the text, inferences generated by the reader and background knowledge resulting in sophisticated representations of text events (Yarkoni, Speer, & Zacks, 2008). Therefore, although it is important to study all the component processes involved in comprehension, the importance of studying higher-level comprehension processing must be stressed (Cain & Oakhill, 2006).

The Event-indexing model provides a theoretical framework of situation model construction and representation (Zwaan, Langston, & Graesser, 1995a; Zwaan & Radvansky, 1998). Within this framework, the reader constructs a situation model based on information provided in the text and own prior knowledge (Gernsbacher, 1990). A number of key dimensions of narrative texts such as time, space, causation, protagonist character, goals and emotions are represented in a situation model (Zwaan, Magliano, & Graesser, 1995b; Zwaan & Radvansky, 1998). The reader monitors text along these dimensions and integrates information to build a coherent and richly-connected representation. The process of incorporating or integrating a new clause or event into the situation model is referred to as *updating*. According to the *processing load hypothesis*, it is easier to integrate new events into the evolving situation model, and update the model when they share indices with previous events. Thus, readers construct situational level representations gradually by continuously updating information from the different dimensions, and integrating it with prior knowledge, resulting in 'in-depth' understanding of the text (De Koning & van der Schoot, 2013).

One of the key component skills in reading comprehension is

'comprehension monitoring', which refers to the process by which readers gauge their understanding of a text (Cain, Oakhill, & Bryant, 2004). Comprehension monitoring is broadly understood to involve detecting and, possibly, resolving inconsistencies (van der Schoot, Reijntjes, & van Lieshout, 2012). Situation models provide a useful framework to study comprehension monitoring skill. While reading, the reader identifies events and represents them along the different dimensions (time, space, protagonist, causality, and intentionality) in the situation model. As the text unfolds, the reader keeps *updating* the situation model. If the new event contains information that is consistent with previous information (or in other words, shares indices with previous events), it is readily integrated into the evolving situation model. However, if the new event contains information that is inconsistent with previous information, then it cannot be readily integrated into the situation model and is thought to be indicative of comprehension breakdown (Albrecht & O'Brien, 1995; Rinck, Hahnel, & Becker, 2001). Therefore, the mismatch between information presented initially and information coming later on in the text creates the opportunity to test whether different dimensions (and information) are being represented at the situation level.

Current Research on Situation Models

The focus of research on text comprehension has shifted from being a study of construction and retrieval of mental representation of the text to understanding the processes involved in constructing meaning (Zwaan, Langston & Graesser, 1995a). The current research on situation models has broadly attempted to examine the processes involved in creating situational level representations and representation of the situation model in memory. Research in recent years has begun to answer questions relating to construction of the situational level of representation, and the

content represented in these models. Studies have examined various aspects of situation models such as effects of instruction on type of representations created, factors influencing the construction of situation models, processes involved in constructing situation models, and inter-relationships between the various situational dimensions among others by means of complementary correlational and experimental methodology.

Studies using behavioural measures such as change in reading times show that temporal and protagonist information is routinely represented in situation models (Rinck et al., 2001; Rinck & Weber, 2003; Zwaan, 1996), even in conditions where attention of the reader is manipulated and directed to another dimension (Therriault, Rinck, & Zwaan, 2006). Intentionality or goal monitoring has been documented, for example, objects relevant to protagonist goals are more accessible than irrelevant but current location objects (Lutz & Radvansky, 1997), and accessibility in memory of objects is mediated by their relevance to protagonist goal fulfilment (Rinck & Bower, 2004). Causal relations between events, objects and protagonists are represented as causal dimension information (Trabasso & Suh, 1993; Zwaan, Radvansky, Hilliard, & Curiel, 1998). Spatial information is represented in situation models (Rinck et al., 2001), especially where it is causally relevant (Jahn, 2004), facilitated with visuals (Zwaan et al., 1998), or with explicit instructions (Therriault et al., 2006). Thus, there seems to be support for the protagonist, intentional, spatial, causal and temporal dimensions being represented in situation models as proposed by the event-indexing model.

The current study focuses on the temporal dimension. Considering that studies examining situation models have consistently found evidence supporting some obligatory representation of temporal information, this seems like a logical

place to start looking at situation models in groups other than healthy adults, including other age groups and clinical populations.

Temporal Dimension of Situation Models

There is no one universal definition or conceptualisation of time (Therriault & Raney, 2007). For example, temporal duration, succession, temporal order, and temporal perspective all represent different aspects of time that can be examined (Therriault & Raney, 2007; Rinck, Gamez, Diaz, & de Vega, 2003; Zwaan, Madden, & Stanfield, 2001; Zwaan & Radvansky, 1998).

In real life, events are experienced as a continuous flow but language allows for movement of events in time (Zwaan et al., 2001). Therefore, sentences must contain cues about temporal relations between the described events, and their occurrence in the text. The reader must work out the correct order of occurrence of events in order to identify motivations behind actions, generate inferences and causal links between events (Zwaan & Radvansky, 1998). Thus, the reader establishes a time line of events relative to each other, and to their mention in the text. The construction of this time line of events is motivated by the *iconicity assumption* (Dowty, 1986), according to which, readers assume that the order in which they encounter events in a text matches their chronological order. A version of the iconicity assumption called the *strong iconicity assumption* (Dowty, 1986; Zwaan 1996) extends this notion, stating that the reader further assumes that contiguous events are described in contiguous sentences. Taken together, this means that readers assume that an incoming story event immediately follows the previously mentioned event, and events narrated in adjacent clauses (or sentences) are contiguous in time. Thus, the default assumption of the reader is that each current model is the continuation of the last event represented in the integrated model. The use of time

adverbs such as *before/after*, time adverbials such as *one month later,* and verb tense cue the reader to override this default assumption, and use these temporal markers to (re)locate the event on the time line (Zwaan et al., 2001; Zwaan & Radvansky, 1998). Hence, readers represent temporal information encoded at each clause level, and use temporal markers as foregrounding cues.

Research findings on the temporal dimension. Various studies (for example, Rinck et al., 2001; Zwaan & Radvansky, 1998; Therriault & Raney, 2007; Rinck & Weber 2003; Therriault et al, 2006; Zwaan, 1996; Rinck et al., 2003) have found evidence that temporal information is represented in situation models. Even though these studies have looked at different conceptualisations or types of time (e.g. temporal order, duration, shift) using different measures (e.g. word recognition latencies, reading times, eye movements), the findings all suggest that temporal information is crucial in building coherent situation models (Therriault et al., 2006). A discussion of the temporal dimension findings should encompass type of temporal information studied, guiding methodologies and measures, and could be structured around findings concerning 'temporal discontinuity' and 'temporal inconsistency' effects.

Temporal discontinuity. Research on the temporal discontinuity effect stems from the violation of *iconicity assumption* and *strong iconicity assumption* taken together with the *processing load hypothesis*. A violation of the iconicity assumptions would lead to increased cognitive processing load as the current situation model would differ from the integrated model along the (time) dimension. Therefore, sentences containing time shift signals, such as temporal adverbials (e.g., *a moment later/ an hour later/ the next day*), would lead to increased cognitive load compared to sentences that signal temporal continuity (Rinck & Weber, 2003). The

increased cognitive load is typically measured as increased reading times on these sentences (e.g., Zwaan, 1996; Rinck & Weber, 2003; Therriault et al., 2006; Therriault & Raney, 2007).

Zwaan (1996) studied the effect of temporal shift on comprehension and found increased reading times on sentences coding time shifts. This finding is consistent with the predictions of the violation of strong iconicity assumption. It can be assumed that the reader takes the time shift signal (temporal adverbial) as cue to reduce the activation of information prior to the time shift, and set up a new time interval, thereby, causing momentary increase in online processing load. This study also identified plausibility, scenario boundary expectation violations, and stylistic oddities as potential factors that could cause increased processing load resulting in a pattern of results similar to disruption of temporal continuity. Taken together, the results from this study suggest that temporal discontinuity leads to increased reading times, however, the loci of this effect is not conclusive as to where readers set up a new time interval. Subsequent studies (Rinck & Weber, 2003; Therriault et al., 2006) examining the effect of shift on multiple dimensions using reading times as dependent measure, have found support for the hypothesis that temporal discontinuity or shift increases the processing load involved in sentence comprehension.

Temporal inconsistency. Research on temporal inconsistency effect stems from violation of the *processing load hypothesis*. The argument is that if a certain dimension or type of information is represented in a situation model, then there should be comprehension difficulties upon encountering information that is inconsistent with the previously represented information (Hyona, Lorch, & Rinck, 2003). Inconsistency detection paradigm has been used to study various dimensions

such as character (Albrecht & O'Brien, 1993), goal information (Poynor & Morris, 2003), spatial information (O'Brien & Albrecht, 1992) and temporal information (Rinck et al., 2001; Rinck et al., 2003; van der Schoot, Horsley, & van Leishout, 2010). In research on temporal inconsistency, reading times and eye tracking measures have been used to support the claim that comprehension of temporal information is disturbed if this information is inconsistent with information already represented in the situation model due to difficulties with 'updating' the model (Rinck et al., 2003). Studies (such as by Rinck et al., 2001; van der Schoot et al., 2012; Therriault & Raney, 2007) using reading times as dependent measure have found that readers represent different types of temporal information in their situation model, and the increased reading times for inconsistent sentences can be attributed to difficulties in updating the model.

Recently studies have started using eye movements to examine temporal inconsistency effect with entire text presented on screen at once (in toto text presentation) (Rinck et al., 2003; van der Schoot et al., 2012). These studies included measures of first-pass and second-pass fixation durations, and regressions to earlier parts of the text as reflecting cognitive strategies employed to resolve comprehension difficulties. The findings from these eye movement studies suggest that comprehension of temporal information is affected if the information is inconsistent with previous information. Inconsistent temporal information causes readers to look back to previous sentences that contain temporal information, and to re-read that sentence in order to solve the inconsistency. Like sentence-by-sentence reading times of the self-paced reading moving window method, eye tracking measures suggest that temporal inconsistencies cause difficulty in updating situation model.

Methodological issues with conventional measures. The conventional

measures used to investigate the temporal dimension of situation models have been reading times and eye movements. A sentence-by-sentence moving window reading task is typically used to collect reading times and reliably indicates comprehension breakdown by way of increased reading times for temporally inconsistent information. Such a presentation limits the number of reading strategies available across readers and texts (Staub & Rayner, 2007). However, it is not reflective of normal reading experience, and does not allow for look-backs, thereby, severely limiting any inferences about the active attempts of the reader to overcome comprehension breakdown (Rayner, 1998; Rinck et al., 2003; van der Schoot et al., 2012). Rinck et al. (2003) raise the possibility that sentence-by-sentence presentation may amplify the reading time increase for inconsistent information. It could be that this presentation manner pushes the reader more towards memory search to resolve inconsistencies.

Eye-movement patterns such as fixation paths, gaze durations, and re-readings provide indications of online processes involved in building and monitoring comprehension (Hyona et al., 2003). Eye tracking using in toto text presentation provides a more natural reading experience, and does not impose any constraints on the strategies employed during reading (Staub & Rayner, 2007). However this lack of restriction can influence the extent to which conventional eye tracking measures of first-pass and second-pass fixation durations accurately indicate online processing differences (Rinck et al., 2003; Kinnunen & Vauras, 2010). Different readers may use different strategies across different texts. Moreover, the interpretation of eye tracking measures is difficult as it is not yet fully understood how these measures (e.g., first fixation time, probability of a regression) are linked to specific cognitive events (Witzel et al., 2012).

The Present Study

Taking the view that comprehension is the goal of reading, and difficulties in comprehending texts can have far reaching negative consequences in school years and beyond, the overarching goal for this study was to increase the understanding of cognitive processes involved in comprehension monitoring. Previous studies have shown the utility of self-paced reading times as an informative indicator of high-level cognitive processes underlying reading comprehension (van der Schoot et al., 2012), while eye tracking measures provide a valid picture of what these high-level processes might be (Kinnunen & Vauras, 2010).

The self-paced reading method and its measure of reading times, and eye movements with its measures of first-pass and second-pass fixations provide comparable results and inferences made from very similar data (Kinnunen & Vauras, 2010; Rinck et al., 2003). Therefore, these two measures have generally been used in an either-or manner (e.g., Rinck et al., 2003; van der Schoot et al., 2012). These techniques have the potential to be combined into a methodology that could provide detailed information regarding comprehension processes. Such a combined methodology could reflect both 'evaluative' and 'regulative' aspects (Kinnunen & Vauras, 2010) of comprehension monitoring by way of increased reading times on comprehension obstacles, and increased look-backs and pattern of gaze durations respectively. A combined methodology could seek a better balance between 'naturalness' and the 'ability to indicate characteristics of online processing of text' (Witzel et al., 2012) and address some of the criticisms of the individual methods.

This study seeks to combine the sentence-by-sentence self-paced reading paradigm task with eye tracking measures to provide *complementary* information. As the reader encounters a comprehension obstacle, an increase in cognitive processing

load would be reflected in increased reading times, while eye movement data would provide indication about cognitive processes that could account for the increased processing load. Therefore, eye tracking measures selected were total fixations on regions of interest during period of interest, specifically, which parts of the text was the reader looking at during periods of increased reading times. This is assumed to reflect cognitive strategies engaged by the reader to resolve comprehension breakdown. The reader could use a strategy of slowing down to re-read information, or look back at previously read parts of the text (Hyona et al., 2003) and re-read those parts, or to think up some resolution for the inconsistency (Yuill, Oakhill, & Parkin, 1989). This proposed methodology is expected to provide some indication regarding the comprehension-repair strategies employed by the reader.

The Experiment

Discontinuity effects manipulation

Discontinuity effects manipulation of the Experiment was designed to examine the effects of temporal shifts on on-line processing of texts and replicate Zwaan's (1996) findings on effects of temporal discontinuity. In previous studies, texts have included a no-shift or continuous condition denoted by a 'moment later' and a shift condition denoted by 'a day later' (e.g., Radvansky et al., 2001; Zwaan, 1996; Radvansky & Copeland, 2010). However, the shift that is assumed to reflect a 'meaningful temporal shift' could make the scenario implausible, for example, "Jamie started typing. *A moment/a day later*, the telephone rang". The increase in reading time on a sentence containing the temporal shift could then also be interpreted as reflecting the difficulty in incorporating an implausible event into the model rather than a temporal shift (considering that typing for a day is not very plausible) (Speer & Zacks, 2005; Therriault & Raney, 2007). Therefore, the

following changes to the stimuli were made in an attempt to separate the effect of plausibility and stylistic violations from temporal discontinuity effects. Firstly, the temporal adverbial that introduced the time shift was meaningful, and plausible for the story scenario, and cued a change in chronological distance while still remaining within the scenario boundary. The magnitude of shift varied between continuous (moment/minute) to intermediate (hour) to long shift (day). However, even the long shift was plausible within the specific story scenario. Secondly, the placement of the temporal adverbial was varied (on the same sentence) to make the text appear natural and less synthetic. Thirdly, to reduce any stylistic influence as advised by Zwaan (1996), the temporal adverbial varied (e.g., *a day later/the next day/later that day; a moment later/a minute later*) based on what was most natural in the story context.

The second goal of this manipulation was to explore whether eye movements can provide additional information and insight into the processes involved in resolving temporal discontinuity. The texts were presented sentence-by-sentence in a self-paced manner with each sentence staying on the screen until the entire text was present on the screen. The third goal was to create a set of stimuli in English that could be used to test the effect of temporal discontinuity on situation model building and updating. It was hoped that this stimuli set could then be used to test reading comprehension in bilinguals, English as second language learners (ESL), and individuals on the Autism Spectrum Disorder at a later stage. The dependent measures identified for this experiment were reading times for the sentence containing temporal adverbial (target sentence), and eye movement measures of total fixation duration on predetermined regions of the target sentence. Reading time on a sentence was defined as beginning when the sentence first appeared on the screen and lasting until the next key-press.

Hence, the predictions for discontinuity effects manipulation of the Experiment were (a) there would be an effect of temporal discontinuity, specifically, there would be increased reading times on shift sentences compared to continuous sentences; (b) for eye movements, readers should have longer total fixation duration on the part of the target sentence that contains the temporal adverbial and cues discontinuity.

Methods

Participants. Fifty undergraduate students from Macquarie University participated in the study to receive either monetary compensation of not more than $15 dollars or credit for course work. All participants were native speakers of English and had normal or corrected-to-normal vision. It was decided from the outset to remove all outliers (participants more than 2 standard deviations away from mean) and participants achieving less than 80% accuracy score in the comprehension questions. A total of 3 participants were removed due to poor comprehension scores and 1 participant removed due to not having enough trials. The analyses presented are based on the remainder of participants.

Materials. In discontinuity effects manipulation, the texts related to the temporal continuity aspect of temporal information processing, were without any contradictions, and plausible for any magnitude of temporal shift. Each text was five sentences in length. The structure of the experimental texts was such that the first three sentences introduced the characters, goals and set up the event. The fourth sentence was the *target* sentence and presented temporal information with regard to temporal continuity or shift, and the fifth (final) sentence was the wrap-up sentence providing the ending. The *target* sentence was in two parts presented on the same line. It began with protagonist action and the subsequent sentence contained the temporal adverbial and unrelated event. The rationale behind this presentation was to

preserve readability and to reduce the effects of stylistic features.

1. *[Introductory sentence 1]* David and his wife went to see an exhibition of impressionist paintings.
2. *[Introductory sentence 2]* They both loved going to the art gallery and looking at the paintings.
3. *[Introductory sentence 3]* They were both artists themselves and spent hours discussing art.

4a. *[Target sentence-Continuous]* They entered the exhibition. A few moments later, David had an idea.

4b. *[Target sentence-Shift]* They entered the exhibition. A few hours later, David had an idea.

5. *[Final sentence]* He would make a painting in the impressionist style for their anniversary.

The participants answered a true/false comprehension question that was unrelated to temporal information at the end of each text. Accuracy on comprehension questions was measured to ensure that participants attended to the texts.

Initially, 20 experimental texts were created and presented to participants. However, on further consideration, eight texts encoded temporal shift in both versions and were excluded from main analyses and were analysed separately. All the experimental texts are attached as *Appendix* A. The filler texts for this manipulation were the texts used in the Inconsistency effects manipulation of the experiment. The study was set up to include 2 manipulations running concurrently with experimental texts for each acting as fillers for the other. Even though all the texts related to temporal information, they coded a variety of temporal information and were logically consistent. The *continuous* version in this discontinuity manipulation and the *consistent* version in the inconsistency manipulation would read as completely coherent texts. There is no reason to assume that any particular type of sentences or (temporal information) would attract the readers' attention more or less than others.

Equipment and procedure. An EYELINK 1000 desktop mount eye-tracker with chin-rest was used to measure eye movements and reading times of the participants as they read the texts. The EYELINK 1000 system uses a corneal reflection method in combination with pupil tracking, resulting in stable tracking of eye position. Although viewing was binocular, signals were recorded from one eye only. Before the experiment started, the eye-tracker was adjusted and calibrated using a 9-point calibration grid presented on the computer screen. The full 9-point calibration was performed at the start of the experiment and after every 10 texts. A 1-point drift correction was performed before each text.

Participants were seated approximately 70 cm from the screen displaying the texts. The texts were presented in Courier font 24 against a grey background in white colour for ease of reading. Presentation was *cumulative,* with each sentence staying on the screen until the entire text was present. The text presentation was representative of normal reading experience with the text starting at the top left corner of the screen and each subsequent sentence appearing underneath the previous sentence. Each sentence fit on a single line on the screen. The presentation of the sentences was self-paced with the press of the space bar. The participants were instructed to read the texts carefully with the purpose of answering a comprehension question at the end of the text. The comprehension question was answered by using specially marked keys (z for true and / for false). It took the participants approximately 40 minutes to complete the experiments. The first three texts were practice texts to familiarize the participants with text presentation and key-press response for the comprehension question. The order of text presentation was randomised. The texts were counterbalanced across participants and conditions such that each text was equally likely to appear in the continuous and shift conditions to

ensure full combination of conditions and materials.

Analysis. The experiment followed a one factor (continuous vs. shift) within-subject design. Reading time was defined as the time between the target sentence (Line 4) appearing on the screen and the participant pressing the button to advance to the next sentence (Line 5). To reduce the error variance due to variations in sentence length, reading time for each target sentence was divided by the number of syllables in that sentence. Reading times that were 2 standard deviations from individual participants' mean were rejected as outliers resulting in the removal of no more than two trials per participant. Reading times were subjected to repeated measures t-tests, with participants (t_1) and items (t_2) as random factors. Eye-tracking analyses considered participants' eye-movements during the reading time (i.e., the interest period for each trial was the same as the reading time). The two sentences on the target sentence (line) were considered as two separate interest areas. The dependent variables were the total gaze durations (i.e., sum of all fixations) on each of the two parts of the target sentence (first part- the protagonist action sentence; second part- the temporal adverbial and unrelated event sentence).

Results and Discussion

The results of discontinuity manipulation are presented in Table 1, which shows reading times per syllable for the target sentences and eye movement analysis for target sentence.

Reading times. To test the hypothesis that reading temporal discontinuity (shift) sentences would increase reading times relative to continuous sentences, mean reading times for continuous and shift target sentences were compared using paired t-tests. The analyses showed a statistically significant increase in reading times for

shift sentences (M = 194, SD = 45) compared to sentences encoding continuity (M = 182, SD = 46) both by participants, $t_1(45) = 2.69$, $p = 0.01$, cohen's d= 0.39 and items, $t_2(11) = 4.90$, $p < 0.001$, Cohen's d = 1.41.

Table 1

Mean Syllable Reading Times and Total fixations on First and Second Part of Target Sentence (in Milliseconds, with Standard Deviations) in Experiment 1

	Continuous		Shift			
	M	*SD*	*M*	*SD*	*t*	*p*
Reading Times	181	46	194	44	2.69	.01
Total fixations first part target sentence	153	46	161	42	1.01	.31
Total fixations second part target sentence	143	42	145	40	0.45	.65

Reading times per syllable for the final (wrap-up) sentence were analysed for both continuous and shift conditions to check if the effect of discontinuity spreads down the text. The results was non-significant $t_1(46) = .827$, $p = .41$; $t_2(11) = .958$, $p = .359$. ANOVAs were performed on the reading times with text (included- coding continuous to shift adverbial vs. excluded – coding intermediate to long shift) and condition (continuous vs. shift) as repeated measures. In the by-subjects analysis, text and condition were within subject factors. There was main effect of text [$F_1(1, 46) = 23.80$, $p = .000$] and significant interaction between condition and text [$F_1(1, 46) = 6.50$, $p = .014$]. For the by-items analysis, text were between-item, and condition was within-item factor. There was no main effect of condition when all texts were included [$F_1(1, 46) = 1.29$, $p = .262$; $F_2(1, 18) = .83$, $p = .373$].

Eye tracking analysis. The reading time analysis showed that participants spent longer reading the target sentence in the shift condition than in the continuous condition. However, this data does not provide any indication of what the readers were focusing on or doing to account for the increased reading time. Therefore, the fixation durations on the target sentence for the shift condition was analysed. The eye-tracking data of 1 participant was removed due to difficulties with measurement leaving 45 participants. The gaze duration per syllable on the two parts of the target sentence were analysed via ANOVA with condition (continuous vs shift) and sentence (first versus second) as repeated measures. There was no main effect of shift/continuity [$F_1(1, 45) = 1.149$, $p = .290$, $\eta_p^2 = 0.025$; $F_2(1, 11) = 2.564$, $p = .138$, $\eta_p^2 = 0.189$] and no interaction between condition and sentence [$F_1(1, 45) = .421$, $p = .520$, $\eta_p^2 = 0.009$; $F_2(1, 11) = 1.006$, $p = .337$, $\eta_p^2 = 0.084$]. Mean fixation duration on the protagonist action sentence (first part of the target sentence) compared to the temporal adverbial with unrelated event sentence (second part of the target sentence) was significantly longer by-participants analysis although this effect was not significant by items [$F_1(1, 45) = 6.022$, $p = .018$, $\eta_p^2 = 0.118$; $F_2(1, 11) = 1.471$, $p = .251$, $\eta_p^2 = 0.118$].

The findings from this experiment replicated the temporal shift effect despite (a) changing the presentation method, (b) changing the stimuli so that they weren't confounded with plausibility, or scenario boundary violations, and (c) removing stylistic oddities.

Inconsistency effects manipulation

Inconsistency effects manipulation of the Experiment came from a recommendation by Rinck et al. (2003), suggesting that a combination of reading time measures and eye movements might provide better insight into the cognitive processes involved in processing temporal inconsistencies. Thus, this manipulation was designed with three goals in mind. The first was to replicate inconsistency effect findings (Rinck et al., 2001; Rinck et al., 2003), and the second was to examine the validity of a hybrid methodology incorporating measures of two ecologically valid measures of on-line text comprehension- namely, eye movements and sentence reading times during undisturbed reading of short texts presented sentence-by-sentence in a cumulative manner. Specifically, the aim was to study the pattern of reading times and eye movements occurring during the processing of inconsistent temporal information compared to those associated with consistent information. The third goal of this study was to create a set of stimuli in English that could be used to test temporal inconsistency effect on situation model building and updating as in the previous experiment.

The inconsistency effects manipulation followed the structure of the inconsistency paradigm experiment used previously (e.g., Rinck et al., 2001; Rinck et al., 2003; van der Schoot et al., 2010) in studying situation models with an additional manipulation of text length. The aspect of interest for reading behaviour was pre-defined for both measures. For reading times, the dependent variable was the time taken to read the *target* sentence. For eye movements, the aspect of interest was eye movements during periods of increased reading times. Therefore, the dependent measures were total duration of fixations on pre-determined areas of interest (target sentence and time sentence), and regressions to earlier parts of the

text, specifically, from target to critical time sentence. Reading time on a sentence was defined as in the discontinuity effects manipulation.

The predictions for this manipulation were (a) there would be an effect for temporal inconsistency, specifically, there would be an increase in reading times on inconsistent compared to consistent sentences; (b) this effect would be seen for both global and local conditions. For eye tracking data, after encountering an inconsistency, the reader would (c) spend more time fixating on the target sentence area; (d) be more likely to regress straight back to the critical time sentence; and (e) spend more time fixating on the critical time sentence.

Methods

Participants. Participants were fifty undergraduate students from Macquarie University. However, the data of twenty-two participants could not be used, as due to a technical fault, these participants were not presented with the full combination of texts and conditions. Three further participants were excluded due to achieving less than 80% accuracy score in the comprehension questions. Hence, the following analyses are based on the data of 25 participants.

Materials. A total of 20 experimental texts were presented to the participants. The first sentence was the *introductory* sentence and introduced the protagonists and/or topic. This was common in all versions. The second sentence was the *time* sentence that gave critical temporal information and existed in two versions. It was either *consistent* (2a) or *inconsistent* (2b) with the information presented later in the text (*target* sentence). On the surface, the difference between the consistent and inconsistent sentence was minor. The *time* sentence was followed by the *target* sentence in the *local* condition and by 2 filler sentences (third and fourth sentence) in

the *global* condition.

The filler sentences were an extension and elaboration on the protagonists or topic introduced in the first sentence but did not create any link between the time information of the second sentence and the target sentence. The filler sentences were included (in the global condition) to ensure that the critical temporal information presented in the *time* sentence (second sentence) was no longer active in the working memory when the *target* sentence was presented (as the fifth sentence). In previous research 4 to 6 filler sentences of varying lengths have been used (Zwaan, 1996; Rinck et al., 2001; Rinck et al., 2003). However, these multiple short filler sentences reduce the readability of the text and makes the experimental text appear contrived and synthetic. Hence, it was decided to combine short fillers into longer sentences (total length of fillers similar to other experiments) while preserving the readability and naturalness of the text to a greater extent. The *target* sentence was common in all versions. This serves to reduce error variance and increases the power of statistical analyses (Rinck & Weber, 2003). The final sentence was a wrap-up sentence that ended the text. Thus, the length of experimental text was 4 sentences in the *local* condition and 6 sentences in the *global* condition. All texts were followed by a true/false type comprehension question. The filler texts for this experiment were those from the discontinuity manipulation.

1. [*Introductory sentence*] Ania was a bit anxious about interviewing a local politician.

2a. [*Critical Time sentence-Consistent*] She had arranged to meet Tom at the café before the interview.

2b. [*Critical Time sentence-inconsistent*] She had arranged to meet Tom at the café after the interview.

3. [*Filler sentence 1*] Ania and Tom were both journalists and were long-time colleagues working at the local newspaper.

4. [*Filler sentence 2*] Today, they planned to discuss a courtroom story that Tom had been working on for some time.

5. [*Target sentence*] When Tom finally entered the café, Ania was just about to leave for the interview.

6. [*Final sentence*] But it was worth the wait as he had lots of new information to discuss.

In order to control for text effects and ensure full combination of conditions and materials, the different versions of the texts were counterbalanced across the material sets by means of 4 x 4 Latin square design. Hence each text occurred equally often in the local/consistent, local/inconsistent, global/consistent and global/inconsistent conditions across sets and participants. The order in which texts were presented in each set was randomised.

Equipment and procedure. The equipment and procedure in this experiment were the same as in the discontinuity effects manipulation.

Analysis. The inconsistency effects manipulation had two factors- location (local vs. global) and consistency (consistency vs. inconsistency). The interaction of these factors resulted in the formation of a 2 x 2 factor design leading to 4 within-subject conditions. Reading times per syllable computation, and outlier rejection procedure was identical across the two manipulations. Analyses were performed with participants (F_1) and items (F_2) as random factors, and location and consistency as fixed factors.

As in the discontinuity manipulation, eye-tracking analyses considered eye-movements during an interest period corresponding to the reading time. Regions of interest were the target sentence and the critical time sentence, as well as "other", referring to any other sentence on the screen. The dependent measures were the total fixation duration on each of the interest areas as well as the number of direct regressions. Given the relatively small amount of time spent fixating on the critical time sentence during the defined interest period, the data were collapsed across location manipulation. The effect of consistency was investigated by way of repeated measures t-tests by-participants and by-items.

Results and Discussion

Reading times. Figure 1 shows reading times per syllable for the target sentences across the four conditions.

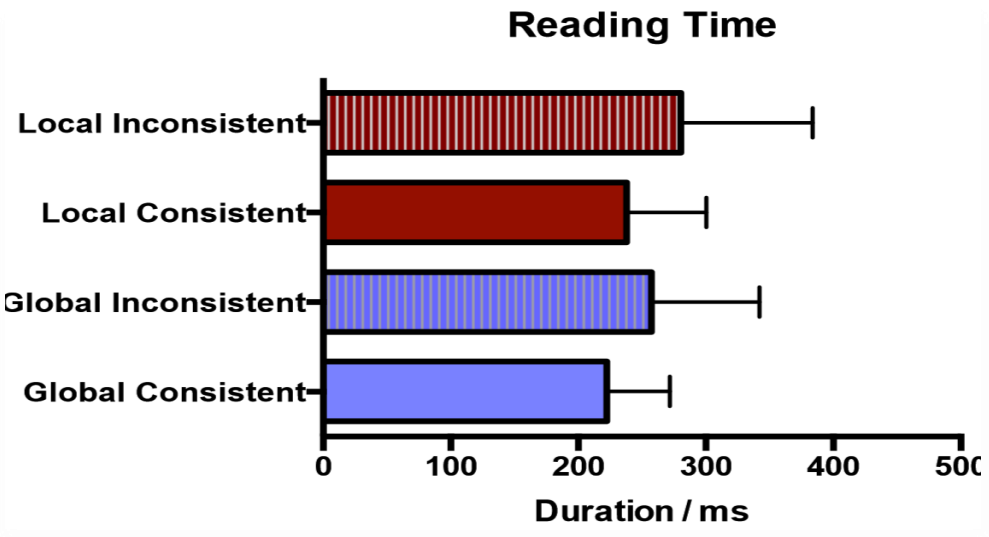

Figure 1. Reading times per syllable on the target sentence as a function of consistency (inconsistent vs. consistent) and location (local vs. global).

To test the hypothesis that inconsistent temporal information sentences would increase reading times on target sentence relative to consistent sentences in both local and global conditions, 2 x 2 ANOVA on the participant (F_1) and item (F_2) were

performed with consistency and location as within-subject variables. Readers took longer to read inconsistent target sentences than consistent target sentences in both local and global conditions. Analysis by subjects showed a mean reading time per syllable of 222 msec (*SD* = 49) in the global consistent (GC) condition, 257 msec (*SD* = 84) in the global inconsistent (GI) condition, 237 msec (*SD* = 62) in the local consistent (LC) condition, and 280 msec (*SD* = 103) in the local inconsistent (LI) condition. The results of the ANOVA showed significant main effects of consistency for both participants and items [$F_1(1,24) = 9.64$, $p < .01$, $\eta_p^2 = 0.287$; $F_2(1,19) = 22.80$, $p < .001$, $\eta_p^2 = 0.546$]. There was a significant main effect for location by-items but not by-participants [$F_2(1,19) = 5.32$, $p < .05$, $\eta_p^2 = 0.219$; $F_1(1,24) = 3.59$, $p = .07$, $\eta_p^2 = 0.130$], though there was a trend towards significance. There was no interaction between consistency and location. These results indicate that readers took longer to read the target sentence when it was inconsistent with previously presented time information for both local [$t(24) = 2.99$, $p = 0.006$, Cohen's d= 0.598) and global conditions [$t(24) = 2.43$, $p = 0.023$, Cohen's d= 0.487).

Eye tracking analysis. Figure 2 shows the total fixation duration per syllable on the interest areas. The focus of eye tracking analysis was to provide complementary information about what could account for this increased reading time upon encountering inconsistency. Therefore, eye tracking data were analysed to show the total duration of fixations (gaze) during the time period between the target sentence appearing on screen and the next sentence appearing. Three regions of interest (ROIs) were identified, namely, the target sentence, the critical time sentence and any other sentence. The proportion of direct regressions from target to time sentence were also analysed.

Interest area analysis. The mean total fixation duration per syllable was

analysed for the interest area of target sentence, critical time sentence and any other sentence.

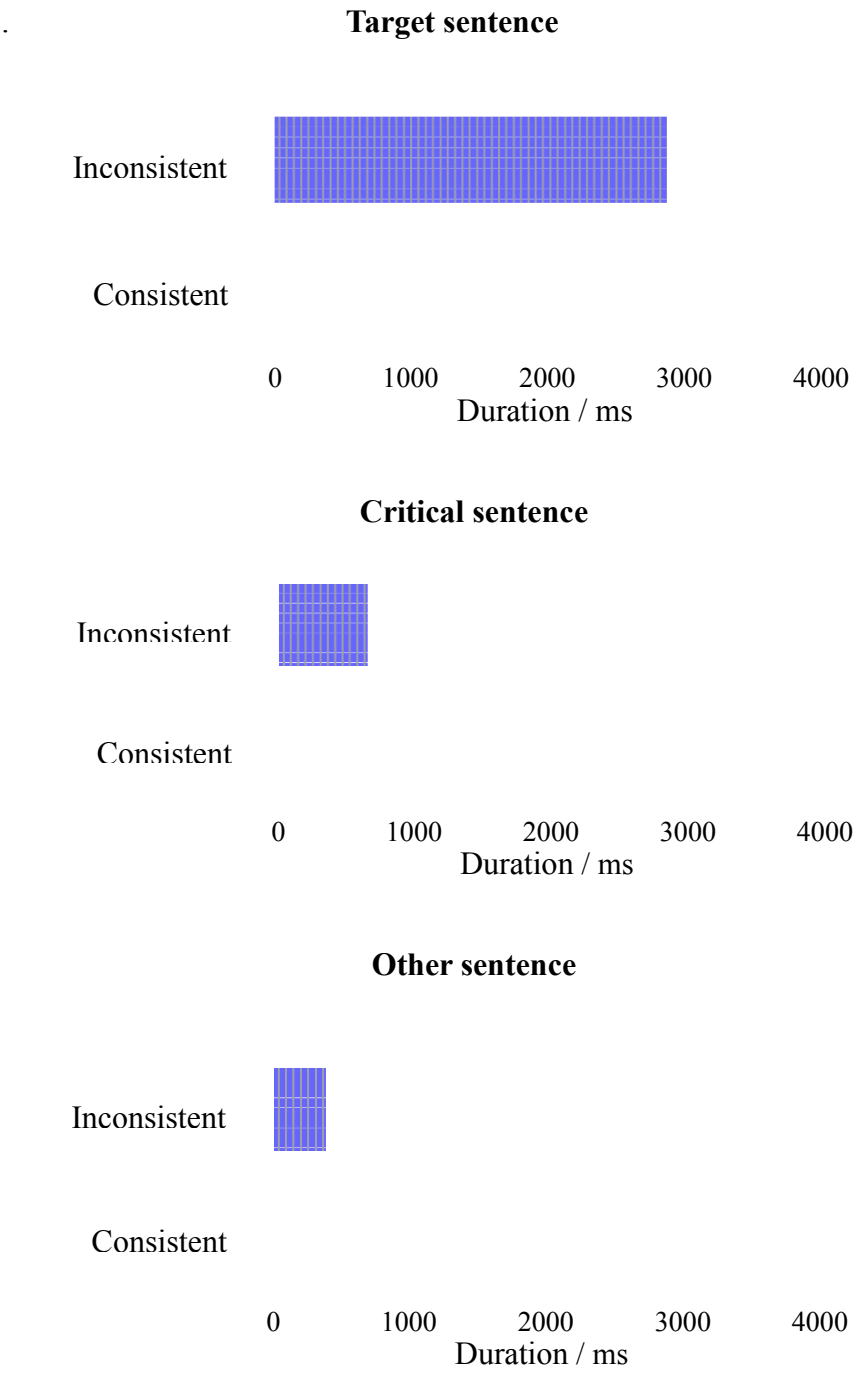

Figure 2. Mean total fixation duration for the interest area of target sentence, critical time sentence and any other sentence during the interest time period of the target sentence appearing and key press for the next sentence.

During the interest time period for target sentence appearing and the key press for the next sentence, participants spent 2580 msec (*SD* = 534) looking at the *target* sentence in consistent condition, and 2855 msec (*SD* = 776) in the inconsistent condition. During the same time period, participants spent 436 msec (*SD* = 354) looking at *critical time* sentence in the consistent condition, and 643 msec (*SD* = 447) in the inconsistent condition; and spent 352 msec (*SD* = 172) on any other sentence in consistent, and 374 msec (*SD* = 187) in the inconsistent condition.

Paired sample t-tests showed significant effects of consistency with a mean fixation duration difference on *target* sentence of 274 msec (*SE* = 103), $t(24) = 2.65$, $p = 0.014$, Cohen's d= 0.531; on *critical time* sentence of 207 msec (*SE* = 71), $t(24) = 2.90$, $p = 0.008$, Cohen's d= 0.581; and on *other* sentences of 21 msec (*SE* = 47), $t(24) = 0.450$, $p = 0.656$, Cohen's d= 0.09. These results indicate that consistency has an effect on the amount of time fixating on parts relevant for resolving the inconsistency. Specifically, the results suggest that when readers encounter an inconsistency, they are more likely to re-read that information, and to revisit information presented previously to resolve the inconsistency than to read other parts of the text randomly.

Regressions. Figure 3 shows the mean number of regressions per condition.

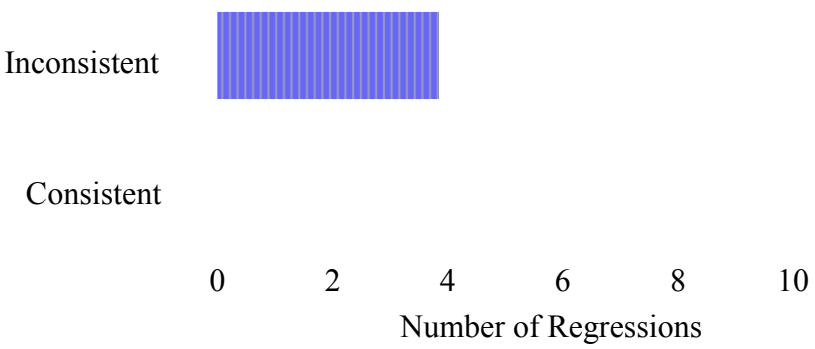

Figure 3. Mean number of direct regressions per condition from target sentence to critical time sentence in consistent and inconsistent conditions.

For the purpose of this experiment, only direct regressions from target to time sentence were counted and are represented in Figure 3. Regressions were analysed across consistent and inconsistent conditions with a Wilcoxon signed-rank test (Z= -2.284, p = 0.022). The results showed that readers were more significantly more likely to regress from *target* to *critical time* sentence in the inconsistent condition than the consistent condition.

Results from this manipulation replicate the inconsistency effect findings with increased reading times for inconsistent target sentences in both local and global conditions. Eye tracking analyses provides some indications of the comprehension repair strategies employed by the readers to resolve the inconsistency. Readers spent longer reading and re-reading the target sentence, made more direct look backs to the critical time sentence, and spent longer re-reading the temporal information.

General Discussion

The main purpose of this study was to consider the usefulness of a combined sentence-by-sentence paradigm with eye tracking to study the processes involved in comprehension. It was hoped that the combination of these methodologies would offer complementary information that would not only provide a reliable measure of increased processing load during on-line comprehension but also provide some indication of what those processes might be. To this end, the study looked at temporal continuity, and consistency aspects of temporal dimension representation in situation models.

The discontinuity manipulation looked at the effects of temporal discontinuity on situation model updating and found an effect of temporal shift on comprehension.

The results replicate findings from previous studies (such as by Rinck & Weber, 2003; Zwaan, 1996; Speer & Zacks, 2005), and show increased reading time on shift sentences compared to continuous sentences. Readers slow down upon encountering a temporal adverbial that introduces a temporal shift compared to an adverbial that does not introduce a time shift. As expected, the results are consistent with the strong iconicity assumption (e.g., Dowty, 1986) which proposes that the default assumption of readers is that subsequent sentences in a text relate subsequent and contiguous events. Therefore, if the reader comes across a time adverbial introducing a time shift, then this default assumption must be supressed resulting in increased on-line processing load (Zwaan, 1996). This increased processing load can be thought to reflect the cost of overriding the default strong iconicity assumption and updating the situation model to set up the new time interval.

The results from this manipulation also replicated previous findings that the increase in processing load is not parallel to the size of the temporal shift. Zwaan (1996) found significant difference in reading times between continuous and intermediate chronological distance denoted by *moment* vs. *hour later* respectively, but not between the intermediate and far conditions denoted by *an hour* vs. *a day later* respectively. In the current study, the texts that coded the chronological distance from *an hour* vs. *a day later* did not elicit any significant difference in reading times. This can be taken as support for the strong iconicity assumption, as the increased cognitive load was seen only for texts that required this default assumption to be supressed. In texts where the two versions coded temporal adverbials *an hour later* vs. *a day later*, both required the strong iconicity assumption to be over-ridden, resulting in similarly increased processing load and corresponding increase in reading times. Thus, the size or magnitude of the temporal shift introduced by the

adverbial does not seem to be important for its ability to initiate situation model updating, rather, the adverbial merely needs to cause over-riding of the strong iconicity assumption to cause increased processing load.

The results from this experiment also addressed concerns whether stylistic reasons and scenario boundaries could be, at least partially, driving the previously observed discontinuity effect. The choice of temporal adverbials in this experiment was guided by the naturalness, and readability of each pair within the specific scenario of the individual text. As the temporal adverbials used in the experiment varied from *half a second* vs *half an hour later; a minute* vs. *an hour later; few moments* vs. *few hours later; the next minute* vs. *the next morning*, it is highly unlikely that the effect found could be due to the wording of the temporal adverbials. Also, as all the scenarios described in the texts were plausible, and within the expected duration boundary for that scenario in both the continuous and shift conditions, the observed discontinuity effect cannot be attributed to violations of scenario boundary expectations. The pattern of results obtained with these set of stimuli elicit the discontinuity effect with evidence of increased processing load while reading sentences containing temporal shifts.

This leads to the second question asked in the discontinuity manipulation regarding what part of the sentence denoting the shift carries the discontinuity effect. The results from eye tracking were expected to provide some insight into the loci of the new temporal interval. The a priori prediction was that readers would spend longer on the part of the target (sentence) line that introduces the temporal shift and the new unrelated event. That is, the shift condition should result in an increase in total fixation (gaze) for the second part of target sentence but not the first. In fact, if anything, the trend was for the effect of condition to be apparent in the first part of

target sentence, but this fell short of significance.

In summary, the discontinuity manipulation indicates that readers expect subsequent events to appear contiguously in narratives as evidenced by increased reading times for sentences containing time shifts. Moreover, this effect does not appear to be due to stylistic reasons, or violations of scenario boundaries, or plausibility violations as the texts in this experiment were plausible for the scenario in both continuous and shift condition (for example, *driving on the highway for a few minutes or a few hours*) and the wording of the temporal adverbial was varied to best fit the flow of the narrative. However, the eye tracking measures in this case provided little extra insight into the cognitive processes underlying this effect.

The inconsistency manipulation sought to investigate the effects of temporal inconsistency on comprehension. The goal for using the combined methodology was to provide insight into what cognitive processes, and strategies could account for the increased cognitive load observed during processing of inconsistencies. The results bear out with increase in reading time measures indicating increased cognitive load upon encountering temporal inconsistencies in text. This can be taken as evidence that readers monitor temporal information, and keep it active during text comprehension. As expected, there was a strong effect of consistency. Readers take longer to read target sentences that are inconsistent with previously provided temporal information compared to sentences consistent with previous temporal information. This effect was significant for both local and global conditions by items and marginally significant by participants. Contrary to expectations, there was no interaction between condition and location (local versus global). This could be due to the entire text being visible, and all participants being skilled readers. Such a manipulation would be expected to show a bigger effect under conditions when

working memory is under stress, such as in a moving window presentation. For individuals with poor reading comprehension skills, or working memory limitations, a manipulation of location of information, and subsequent inconsistency would yield larger impact. These results fit in well with previous studies investigating the temporal inconsistency effect (see Rinck et al., 2001; Rinck et al., 2003; van der Schoot et al., 2012).

The eye tracking measures used previously in studies examining temporal inconsistency effect have used first-pass fixations and second-pass fixations on target and critical temporal information sentences. However, first-pass fixation duration is not suitable to provide information about cognitive processes that can account for the increased processing load suggested by increased reading time measures. It is simply a measure of how long did the reader look at a sentence before exiting the sentence for the first time. The assumption here is that the reader would only make purposeful moves away from the (target) sentence, and that this is reflective of some cognitive strategy to facilitate comprehension. Rinck et al. (2003) found that first-pass fixation durations did not capture the inconsistency effect. Therefore, for the current study, eye movement measures were analysed to furnish a better picture of additional processing recruited to resolve the inconsistency. The results show that during the time period when the target sentence first appeared to the key-press for the next sentence, readers spent longer looking at the target sentence, and the critical temporal information sentence in the inconsistent condition than the consistent condition. Participants spent similar amounts of time looking at other sentences in the text in both conditions during this time. This pattern of total fixation duration suggests that as readers detected the inconsistency, they engaged in strategic comprehension repair strategies. The reader could utilise the comprehension-repair

strategy of slowing down to re-read inconsistent information (Hyona et al., 2003) or think up some resolution for the inconsistency (Yuill, Oakhill, & Parkin, 1989), as evidenced by increased total fixation duration on the target sentence in the inconsistent condition. The reader could also apply the strategy of re-reading previously parts of the text to check the information again (Hyona et al., 2003), as evidenced by increased total fixation duration on the critical temporal information in the inconsistent condition compared to the consistent condition. The eye movement analysis also shows significantly more direct regressions from the target to the critical temporal information sentence in the inconsistent condition than to any other part of the text. These results indicate that readers engage strategic comprehension repair processes when situation model updating is affected. Taken together, the results from inconsistency manipulation suggest that readers are sensitive to inconsistencies of temporal information during text processing. Readers are likely to engage in cognitive strategies such as slowing down reading of the inconsistent information, re-reading that information, look backs to previously presented information and re-reading that information in order to resolve the inconsistency.

Limitations

While this study showed the potential of a combined sentence-by-sentence reading task with eye tracking presented in a cumulative manner, it does have clear limitations. As the presentation of the sentences was self-paced and cumulative, it could be that some participants pressed the key for the next sentence while still reading the current sentence. While the instruction to the participants was to read for comprehension, it could be that some participants created more text base representations. The texts used in the discontinuity manipulation were divided into two groups post-hoc and the inconsistency manipulations lost a number of

participants due to a technical error. The interpretation of eye movement patterns is difficult considering the number of different strategies that participants could employ while reading. Also as all the texts contained temporal information, they might conceivably have sub-consciously primed the participants to temporal information. However, this seems unlikely as none of the participants reported that the texts were about time. The findings using the methodology piloted in this study should be replicated on an equivalent set of texts to establish validity of the measure.

Conclusions and Future Directions

The results from both experiments add to the growing corpus of empirical studies which demonstrate that readers create situation models during comprehension, and that temporal information is represented in these models. Based on the findings of these experiments, it appears that a combined methodology that brings together the advantages of reading time measures, and eye movement measures offers a better picture of cognitive processes required to resolve comprehension breakdowns. Reading time data provides information about periods of interest, and eye movement data provides information about areas of interest. Taken together these two measures can offer a more complete representation of the cognitive strategies, and processes that might be in play based on the area of the text being focused at by the reader.

As the ability to understand written material is key to a successful outcome in society, specific focus on teaching strategies that help achieve this end should be stressed. One such approach could be to focus explicitly on creating situation models during comprehension by way of instructions (van der Schoot et al., 2010). Encouraging the reader to create situation model knowledge is of primary importance for academic success as the representation of both *surface form* and *text*

base are rapidly lost (Radvansky et al., 2001). The processes involved in situation model construction and updating could inform intervention techniques. Educational practices that focus on teaching readers to pick out information relevant to model construction, make inferences, elaborate with prior knowledge, and monitor comprehension would be very helpful for children struggling to comprehend texts. While there is some research on effect of instruction on quality of situation models constructed (van der Schoot et al., 2010), more research is needed to examine and quantify the characteristics of texts that encourage creation of situation models, especially text genres other than narratives such as scientific texts. Further research manipulating other variables such as text complexity, and levels of cohesion could investigate how readers would share cognitive resources between different text representations, and utilise information during comprehension.

While the majority of research on situation models has been conducted on typical adults, there are great possibilities for use in other populations. Considering that situation model level of processing is well preserved in older adults despite general cognitive decline, these processes could be used to understand, and compensate for the consequences of decline in cognitive functioning associated with aging (Radvansky et al., 2001). Examining reading comprehension within the framework of situation models would also be useful for individuals with Autism Spectrum Disorders (ASD). Previous research shows that many individuals with ASD have significant difficulties with merging and assimilating information, making links, and elaborating using prior knowledge, even when they are able to decode and extracting meaning from individual words (Ricketts, 2011; Tager-Flusberg, 1981; Just, Cherkassy, Keller, & Minshew, 2004; Rutter, Mawhood, & Howlin, 1992). Considering that situation models are mental simulations of described events, they

offer an interesting framework to study issues with coherence, and perspective taking.

If the goal of reading is comprehension (Nation, 2005), then the goal of comprehension is to create a situation model (Radvansky et al., 2001). Situation models provide a useful framework to study the cognitive processes that give rise to reading comprehension. The combined methodology and measures piloted in this study are a first attempt to examine the strategies recruited to create, and monitor comprehension.

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APPENDIX

Appendix A: Texts used in the Discontinuity effects manipulation

1, 2 and 3 = introductory sentences; 4a = target sentence- continuous version; 4b = target sentence- shift version; 5 = final sentence. Q = comprehension question.

Text 1

1. Chris had opened a new law practice in London after his move from Paris.
2. He had quite a few clients booked in for meetings in the afternoon.
3. He had lots to do and decided to do all the administration jobs first.
4a. Chris started opening the post. A moment later, he felt a migraine coming on.
4b. Chris started opening the post. An hour later, he felt a migraine coming on.
5. He felt that he was working too hard and should find more time to relax.
Q. Chris lived in London now?

Text 2

1. Frank and his grandson were going fishing in a lake in the mountains.
2. They got up really early and hiked for a couple of hours to the fishing spot.
3. The day was turning out to be rather warm but the water was quite cold.
4a. Frank stepped into the water. A few moments later, he felt nauseous.
4b. Frank stepped into the water. A few hours later, he felt nauseous.
5. He decided to rest for a bit before starting fishing again.
Q. Frank was going hunting in the mountains?

Text 3

1. It was the last day of Eve's vacation at the beach resort.
2. She wasn't looking forward to getting back to work again.
3. It was quite warm already and Eve felt like having a nice refreshing drink.
4a. She settled into her chair. A minute later, a waiter went past with fruit drinks.
4b. She settled into her chair. An hour later, a waiter went past with fruit drinks.
5. Luckily he still had her favourite mango drink left.
Q. Eve was on holidays near the sea?

Text 4

1. Sean was a bartender at an Irish pub in Chicago.

2. There was an important football game on tonight.

3. The bar was already packed full of football supporters when Sean turned the TV on.

4a. The match started. Two minutes later, a fight broke out between two supporters.

4b. The match started. Two hours later, a fight broke out between two supporters.

5. Sean asked both of them to leave as this sort of behaviour was unacceptable.

Q. Sean lived in Ireland now?

Text 5

1. Dorothy was preparing to watch her favourite show on TV.

2. She had been gardening the whole day and felt that she had earned the break.

3. She made some tea and grabbed some snacks to eat while watching her show.

4a. She settled into her chair. A minute later, she heard a loud bang.

4b. She settled in to her chair. An hour later, she heard a loud bang.

5. It was an enormous thunder storm passing by.

Q. Dorothy liked watching TV?

Text 6

1. Amy wanted to be a professional violinist.

2. She practised for a few hours everyday after school.

3. She had had a busy day at school but was looking forward to begin practicing.

4a. She picked up her violin and started. Two minutes later, the doorbell rang.

4b. She picked up her violin and started. Two hours later, the doorbell rang.

5. Amy's friend from school had come to invite her to a party next weekend.

Q. Amy played the violin as a hobby?

Text 7

1. David and his wife went to see an exhibition of impressionist paintings.
2. They both loved going to the art gallery and looking at the paintings.
3. They were both artists themselves and spent hours discussing art.
4a. They entered the exhibition. A few moments later, David had an idea.
4b. They entered the exhibition. A few hours later, David had an idea.
5. He would make a painting in the impressionist style for their anniversary.

Q. The art gallery was showing impressionist paintings?

Text 8

1. Sandra was an established novelist.
2. She had been experiencing writer's block and had not written much lately.
3. She needed to write a rough draft of the story for the meeting with her publisher.
4a. She sat down and started typing. Five minutes later, the phone rang.
4b. She sat down and started typing. Five hours later, the phone rang.
5. It was the publisher calling to postpone the meeting by a week.

Q. Sandra was a struggling writer?

Text 9

1. Teresa was a member of the local theatre company.
2. She was starring as the leading lady and today was the full dress rehearsal.
3. Teresa had been very nervous for the past few days, sleeping and eating poorly.
4a. She stepped on to the stage in her costume. A moment later, Teresa collapsed.
4b. She stepped on to the stage in her costume. An hour later, Teresa collapsed.
5. The other members rushed her to the hospital where they advised her to rest.

Q. Teresa loved drama and theatre?

Text 10

1. Bill was on his way to spend a weekend with his parents.

2. He had had the car serviced and bought snacks and drinks for the drive.

3. Bill left early to beat the morning traffic and was driving up the interstate.

4a. He turned on some music. A few minutes later, Bill exclaimed in anger.

4b. He turned on some music. A few hours later, Bill exclaimed in anger.

5. He had forgotten to leave some food out for his cat.

Q. Bill was going to spend a week with his parents?

Text 11

1. Today was the grand opening of Maurice's new art gallery.

2. He had invited everyone in town, who was important in the arts.

3. The guests started to arrive on time and all seemed to enjoy the opening.

4a. Maurice was feeling pleased. The next minute, he suddenly turned pale.

4b. Maurice was feeling pleased. The next morning, he suddenly turned pale.

5. He had forgotten to invite the local art critic to the gallery opening.

Q. Maurice had owned the gallery for a long time?

Text 12

1. Kay was an instructor at a ski resort.

2. She taught the beginner's classes, close to the ground station.

3. Kay started the day's lesson with making the class practice turning curves.

4a. The class started practicing. Half a second later, there was a loud rumble.

4b. The class started practicing. Half an hour later, there was a loud rumble.

5. They looked up to see an avalanche thundering down the mountain edge.

Q. Kay was learning to ski?

Texts not included in the analysis (coding intermediate to long shift)

Text 13

1. Mike was taking a undergraduate course in statistics.
2. He had always been afraid of numbers but was motivated to do his best.
3. He read up before class and made notes while the teacher explained the topic.

4a. He revised the notes one more time. An hour later, Mike began to feel sick.

4b. He revised the notes one more time. A day later, Mike began to feel sick.

5. He suspected it was the chicken sandwich he had eaten the day before.

Q. Mike was at university?

Text 14

1. Jack decided that it was time to paint his fence.
2. Even though he felt that painting was a chore, it was cheaper to do it himself.
3. He got the materials ready and stripped the old paint off from the fence.

4a. Jack started painting the fence. Later that morning, his son called to invite him.

4b. Jack started painting the fence. Later that evening, his son called to invite him.

5. Jack was delighted with the invite as he always liked to see the grandchildren.

Q. The fence needed painting?

Text 15

1. Steve had a lot on his mind this evening.
2. He had promised a friend to write a column for a senior's magazine.
3. He had no ideas and was spending the evening with his granddaughter anyway.

4a. Steve and his granddaughter built model trains. The next morning, he had an idea.

4b. Steve and his granddaughter built model trains. The next evening, he had an idea.

5. He would write a column about bonding with grandchildren.

Q. Steve was writing a column for a sports magazine?

Text 16

1. Sandra worked as a barista in a Café.

2. Today was her first day back from a very exciting holiday in Perth.

3. She loved the relaxed atmosphere and the friendly people there.

4a. Sandra came into work. She handed in her resignation the same morning.

4b. Sandra came into work. She handed in her resignation the same evening.

5. She had decided to make the move to Perth and open her own café.

Q. Sandra had been to Perth?

Text 17

1. Michael was on his way to Italy on a business trip.

2. His grandparents came from Italy and this was his first trip there.

3. As he checked into the hotel, he inquired about local musical performances.

4a. Michael prepared for the meetings. Later that morning, he received a note.

4b. Michael prepared for the meetings. Later that evening, he received a note.

5. It was a complimentary ticket to a violin performance for the next day.

Q. Michael had grown up in Italy?

Text 18

1. Sue had finally decided to enrol in a photography course.

2. She needed to take photos of wild flowers for a class assignment.

3. She drove out of town and found the perfect spot to take her photos.

4a. Sue went to get a coffee. Later that morning, it began to rain heavily.

4b. Sue went to get a coffee. Later that afternoon, it started raining heavily.

5. It didn't look like she would be able to take the photos of those wild flowers.

Q. Sue was enrolled in a photography course?

Text 19

1. Mikey and his wife were going camping for the first time.

2. They had bought all the gear and had chosen a campsite near a woodland.

3. As they were setting up their tent, they could see dark clouds rolling in.

4a. Soon it started to rain. An hour later, they heard the town was hit by a hailstorm.

4b. Soon it started to rain. A day later, they heard the town was hit by a hailstorm.

5. It was lucky that the storm had passed by without hitting them.

Q. Mikey and his wife were camping near a beach?

Text 20

1. Sally was a volunteer at the local community centre.

2. She was organising a free theatre workshop for the local children.

3. There were a lot of people asking about the workshop.

4a. Sally started talking. After an hour, she put up signs explaining the workshop.

4b. Sally started talking. After a day, she put up signs explaining the workshop.

5. It saved her a lot of time not having to answer the same questions all day.

Q. Sally was involved in the local community?

Appendix B: Texts used in the Inconsistency effects manipulation

1 = introductory sentence; 2a = critical temporal information- consistent version; 2b = critical temporal information- inconsistent version; 3 and 4 = filler sentences for global condition; 5 = target sentence; 6 = final sentence. Q = comprehension question.

Text 1

1. Ania was a bit anxious about interviewing a local politician.

2a. She had arranged to meet Tom at the café before the interview.

2b. She had arranged to meet Tom at the café after the interview.

3. Ania and Tom were both journalists and worked together at the local newspaper.

4. Today, they planned to discuss a courtroom story that Tom had been covering.

5. When Tom finally entered the café, Ania was just about to leave for the interview.

6. But it was worth the wait as he had lots of new information to discuss.

Q. Ania was going to interview a politician?

Text 2

1. Alex and Peter were friends from school.

2a. Peter had football practice right after class but the boys had arranged to meet later.

2b. The boys had arranged to meet right after class but Peter had football practice later.

3. They often met in the afternoon and played computer games.

4. Sometimes they did research for their homework assignments together.

5. The football practice ran over time, so Peter arrived quite late at Alex's house.

6. Alex was busy playing a new computer game.

Q. Alex and Peter knew each other from karate club?

Text 3

1. It was lunch time and Sam hurried down to the cafeteria.

2a. *He bought a coffee and then ate his sandwich.*

2b. He ate his sandwich and then bought a coffee.

3. Sam generally brought lunch from home and ate with his colleagues.

4. They often discussed work issues or plans for the weekend.

5. *While they were talking, Sam accidently spilled some coffee on his sandwich.*

6. He decided to get a cupcake on his way back.

Q. Sam hurried down to the cafeteria at lunch time?

Text 4

1. Carol had been given a lovely pink swimming suit for her birthday.

2a. She went swimming with her friend Tina first and to the movies with her parents later.

2b. She went to the movies with her parents first and swimming with her friend Tina later.

3. Carol and Tina went to the same school and had been friends for a long time.

4. Carol had been looking forward to her birthday for weeks.

5. At the movie theatre, she told her parents how much fun she had had swimming with Tina.

6. She had a lovely day and thanked both her parents very much.

Q. The colour of Carol's swimming suit was blue?

Text 5

1. It was the first day of Tom and Rita's trip to London.

2a. They wanted to go to Westminster Abbey first and to the Tate museum afterwards.

2b. They wanted to go to the Tate museum first and to Westminster Abbey afterwards.

3. They had been looking forward to this trip for ages and had planned it thoroughly.

4. Tom had read the guidebooks and Rita had talked to friends who had been to London.

5. Just as they had planned, they went straight to Westminster Abbey after breakfast.

6. They were very impressed by the sheer size of the building.

Q. Tom and Rita were holidaying in London?

Text 6

1. Laura had just picked up a meal from the Chinese restaurant.

2a. She decided to check her email before sitting down for dinner.

2b. She decided to sit down for dinner before checking her email.

3. There was a deadline for an important project at the end of the week.

4. Once this project was finished she was hoping to take a holiday.

5. By the time Laura finished at the computer, her meal had gone cold.

6. She was glad it came in a microwaveable box.

Q. Laura did not like Chinese food?

Text 7

1. John had arranged to meet his friend Sara at the station.

2a. Sara's train arrived on time at 4:10 pm and John's train arrived at 4:30 pm.

2b. John's train arrived on time at 4:10 pm and Sara's train arrived at 4:30 pm.

3. They had not seen each other for a long time and had a lot to talk about.

4. John had bought Sara's favourite chocolates and some flowers as a present.

5. When he got off the train, Sara was already there waiting for him.

6. They walked into town together.

Q. Sara and John were good friends?

Text 8

1. Katie and Mel had worked very hard on their presentations.

2a. Katie's presentation started at 9:15 and Mel had hers at 9:30.

2b. Mel's presentation started at 9:15 and Katie had hers at 9:30.

3. They had put in a lot of effort and had researched the topics thoroughly.

4. Both had practiced the presentation in front of the family a few times.

5. Mel didn't mind waiting to start her presentation after Katie.

6. The hard work paid off and both girls were given high marks.

Q. Katie got a poor mark for her presentation?

Text 9

1. All the children had arrived well in time for the class to start.

2a. The last lesson of the morning was history and it would last until 12:00.

2b. The first lesson of the morning was history and it would start at 12:00.

3. They were all looking forward to the upcoming field trip to the history museum.

4. It was going to be a whole day event with the travel to and from the museum.

5. The students got impatient when the history teacher was still talking at 12:15.

6. After the lesson the class had a short break.

Q. The students arrived for the class early?

Text 10

1. Every morning Luke took the freeway as he drove to work.

2a. He left at his usual time of 7:00 and met no traffic today.

2b. He left at his usual time of 7:00 and met heavy traffic today.

3. As Luke lived quite a distance from work, he had a fairly long drive everyday.

4. Luke was a morning person and preferred an early start to his day anyway.

5. Luke was pleased to have arrived earlier than usual at work.

6. He had an important meeting that day and was glad for the extra time.

Q. Luke enjoyed his walk to work everyday?

Text 11

1. Mike's best friend Ali had his birthday on the 6th of March.

2a. He emailed a birthday card to Ali on the 5th of March.

2b. He emailed a birthday card to Ali on the 7th of March.

3. They had been friends since college and had met on the first day of class.

4. They were both enrolled in the same degree and came to know each other well.

5. Ali was very pleased to open the card from Mike on his birthday.

6. It was a funny card with singing dancing rabbit.

Q. Ali and Mike were very good friends?

Text 12

1. Mia had been looking forward to today for a while.

2a. She was getting her nails done at 10:00 and a haircut at 12:00.

2b. She was getting a haircut at 10:00 and her nails done at 12:00.

3. Mia liked to take care of her appearance, eating well and exercising regularly.

4. She had recently bought a bicycle and tried to go for a long bicycle ride each week.

5. The hairdresser complemented Mia on her newly painted nails.

6. Mia was very pleased with the compliment.

Q. Mia didn't really care about looks?

Text 13

1. Lea was competing in the university swimming championships for the first time.

2a. She had won a silver medal and 3 days later a gold medal.

2b. She had won a gold medal and 3 days later a silver medal.

3. Lea had been swimming all her life, spending every summer holiday in the pool.

4. Her father was a keen swimmer and had taught her to swim when she was very young.

5. That first time on the podium receiving her silver medal was a very special moment for her.

6. She was looking forward to showing the medals to her father.

Q. Lea enjoyed swimming very much?

Text 14

1. Mary sat in her rocking chair and looked at the photographs in her hand.

2a. A faded photo showed her at a sports event, another taken 10 years later showed her at graduation.

2b. A faded photo showed her at graduation, another taken 10 years later showed her at a sports event.

3. Mary spent a lot of time reminiscing over old photos.

4. She looked forward to seeing old friends again at their annual college reunion.

5. The faded photo at the sports event was the oldest picture she had.

6. Mary leaned back and smiled thinking of how good life had been to her.

Q. Mary sat on the sofa while looking at her pictures?

Text 15

1. Tanya was a keen musician.

2a. She learnt to play the guitar as a young child and 6 years later learnt to play the piano.

2b. She learnt to play the piano as a young child and 6 years later learnt to play the guitar.

3. Tanya credited her music teacher for instilling a love for music in her.

4. She loved listening to the teacher play different musical instruments.

5. *The guitar being the first instrument she ever learnt to play, was still her favourite*.

6. She still had the one she had learnt to play on stored in the attic.

Q. Tanya loved everything about music?

Text 16

1. Mike loved climbing mountains.

2a. He often talked about the climb in Colorado and the one he did in Ohio 2 years later.

2b. He often talked about the climb in Ohio and the one he did in Colorado 2 years later.

3. Mike became interested in climbing after watching a documentary about it on TV.

4. Luckily, he could join the mountaineering club at his university straightaway.

5. The Colorado climb was special as it was his first.

6. He was already training for the next climb in the Nebraska mountains.

Q. Mike had lost interest in mountain climbing?

Text 17

1. Melissa had several tattoos done over the years.

2a. She had a tattoo of a phoenix on her back and 5 years later she got one of a sunrise.

2b. She had a tattoo of a sunrise on her back and 5 years later she got one of a phoenix.

3. As Melissa was a school teacher, at work she wore clothes that covered her back.

4. However at the weekend, she was quite happy to show off her tattoos.

5. She was especially proud of the phoenix as it was her first one.

6. Melissa was thinking about getting a new tattoo on her ankle.

Q. Melissa had tattoos on her body?

Text 18

1. Gloria loved collecting old vinyl records.

2a. Her favourite album was one by Enya and one by the Beatles that she bought 3 years later.

2b. Her favourite album was one by the Beatles and one by Enya that she bought 3 years later.

3. Gloria had bought a special vinyl record player last year from eBay.

4. She also set up a display cabinet to showcase her records and keep them safe from dust.

5. The album by Enya was the first record in her collection.

6. She was looking forward to the vinyl record collectors convention later in the year.

Q. Gloria collected old cassette tapes?

Text 19

1. Eva and Anthony sat together at the breakfast table.

2a. Anthony ate muesli and made a sandwich for work, Eva just drank some juice.

2b. Eva ate muesli and made a sandwich for work, Anthony just drank some juice.

3. The kitchen was new and modern and had a large breakfast table.

4. Through the big kitchen window they could see the flowers in full bloom outside.

5. Eva finished her breakfast first and then had to wait for Anthony.

6. They quickly tidied up the kitchen and left for work.

Q. Eva and Anthony ate breakfast together?

Text 20

1. Vincent and Chris are brothers.

2a. Chris was 4 years younger than Vincent.

2b. Vincent was 4 years younger than Chris.

3. They also had a baby sister called Sophie.

4. Both the brothers were very fond of their little sister.

5. Lately Vincent had started feeling too old to play Chris's games.

6. He much preferred to play with the older boy living next-door.

Q. Vincent and Chris were neighbours?