Priming For Success: Exploring the Role of Repetition Priming in Improvements in Word Retrieval for Unimpaired Speakers and People with Aphasia.

Ella Creet

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Department of Cognitive Science

Macquarie University, Sydney, Australia

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Declaration

The work in this thesis is my own original work. It has not been submitted for a higher degree in any other university or institution. All of the work reported in this thesis was undertaken during the time I was enrolled as a PhD student at Macquarie University, under the supervision of Prof Lyndsey Nickels, as well as Dr Julie Morris and Prof David Howard of Newcastle University, UK. Ethics approval for the studies reported in this thesis was obtained from Macquarie University's Human Research Ethics Committee, Reference No. 5201200905.

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Macquarie University (Australia)

Newcastle University (United Kingdom)

Rijksuniversiteit Groningen (the Netherlands)

Università degli studi di Trento (Italy)

Universität Potsdam (Germany)

General Abstract

Aphasia is a speech and language disorder, most commonly resulting from a stroke. For many people with aphasia, finding the right word to say can be a frequent problem. However, some individuals with aphasia are able to improve their word retrieval simply by attempting to name a picture without any treatment or feedback.

The first experimental chapter in this thesis (Chapter 2) explores this phenomenon, examining changes in accuracy over seven naming attempts at approximately six week intervals in a case series of 23 people with aphasia: four individuals showed significant improvement in naming, but, surprisingly, two showed performance that significantly worsened.

The mechanism underpinning change in performance from repeated attempts at naming in people with aphasia has been hypothesised to be repetition priming. Hence, Chapters 3, 4 and 5 investigate parameters of repetition priming in young and older unimpaired speakers and people with aphasia.

Chapter 3 explores the time course of repetition priming of picture naming in unimpaired young adults, finding significant priming with lags ranging from minutes to one month even though naming stimuli used different pictorial exemplars. There was no benefit from additional repetitions. Chapter 4 extends this to older speakers, finding no significant differences in priming from young adults, although priming was no longer significant for the older speakers at one week. Chapter 5 looks at repetition priming in people with aphasia, finding significant improvements in naming latencies with a lag of several minutes, but not at longer delays. Accuracy only showed priming with four repetitions spaced over one week.

This thesis contributes to a better understanding of a mechanism underpinning treatment improvements in people with aphasia. Additionally, it provides further understanding of repetition priming mechanisms and highlights the importance of examining individual priming effects further. This will help inform both theories of word retrieval and targeted treatment for people with aphasia.

Chapter 1

Introduction

Most of us take for granted our ability to freely communicate our thoughts and desires. We constantly retrieve words fairly automatically and it is relatively rare when we stumble on a word. However, for people with aphasia, this is a constant problem when they speak. Aphasia is a speech and language disorder, most commonly resulting from a stroke. Difficulty in retrieving words is a common symptom of aphasia and is often reported to be the most devastating symptom. Rather than a fluent automatic process, finding the right words is slow, effortful and error prone. While there is evidence of treatments that do lead to significant improvements, for most it remains a debilitating condition.

Whilst aphasia is an extremely diverse disorder with varied language and other cognitive difficulties of differing degrees of severity, this thesis focuses on anomia: a difficulty in retrieving words. The most common way to assess word retrieval difficulties is through a picture naming task where a picture of a single item is displayed, and the individual is asked to name that item. Individuals with anomia struggle to retrieve and articulate the correct name and may substitute words that are related phonologically (in sound) or semantically (in meaning), such as 'hat' or 'dog' for 'cat' (Goodglass, Kaplan & Barresi, 2001). The provision of phonemic cues, such as the first sound of the target word (e.g. /k/ for cat), has been found to significantly increase accuracy (e.g., Jefferies & Lambon Ralph, 2006). This suggests that people with aphasia usually still have the word stored in their mind, but it is difficult for them to retrieve this word based on the picture alone.

There are numerous treatment studies which have reported to improve naming, through a variety of methods (for review see Nickels, 2002b; Wisenburn & Mahoney, 2009). Regardless of the focus of treatment (e.g., semantic or phonological enrichment, orthographic or phonological cueing, repetition), most therapy techniques involve repeated activation of both semantic and phonological representations of the target word. This repeated activation will be explored in further detail below.

The challenge of anomia and its remediation is what inspired the work of this thesis and is explored through a series of four experimental papers. This chapter serves as an introduction to those papers. Firstly, we will briefly describe how word retrieval is achieved under normal circumstances (without any language impairment), and theories of how this is accomplished. Then evidence of word retrieval improvement in people with aphasia, through repeated attempts at naming, will be presented. It has been proposed that both repeated attempts at naming and many treatments of word retrieval share a common underlying mechanism, the same mechanism responsible for repetition priming effects. This concept of priming will be introduced and it is its role within word retrieval that forms the basis for the majority of this thesis. This chapter will conclude with an overview of the chapters to come.

Models of Word Retrieval

Fluent speech in people without language impairment involves the retrieval of around one to three words per second, with an error rate of less than one per thousand words (Butterworth, 1989; Levelt, 1989). At its simplest level, to produce a single word to express a simple concept, the speaker must first select the most appropriate word to represent the meaning they want to convey from a vocabulary of tens of thousands of words. Having selected the word based on meaning, the sounds that make up the word must be combined in the correct order to be spoken.

Most models of word production conceive of word retrieval as involving these two distinct, semantic and phonological, processes (e.g., Butterworth, 1989; Dell, 1986; Garrett, 1975; Levelt, 1989; Schwarz, Dell, Martin, Gahl & Sobel, 2006). Word selection is managed by the lexical-semantic phase where words are organised by meaning, semantic category and function. Word sound is managed by the phonological retrieval phase whereby individual word sounds or phonemes are retrieved and assembled (see Figure 1). The actual articulation of the word is seen as a separate motor process that occurs after lexical processes have completed, and therefore is not focused on in this thesis.

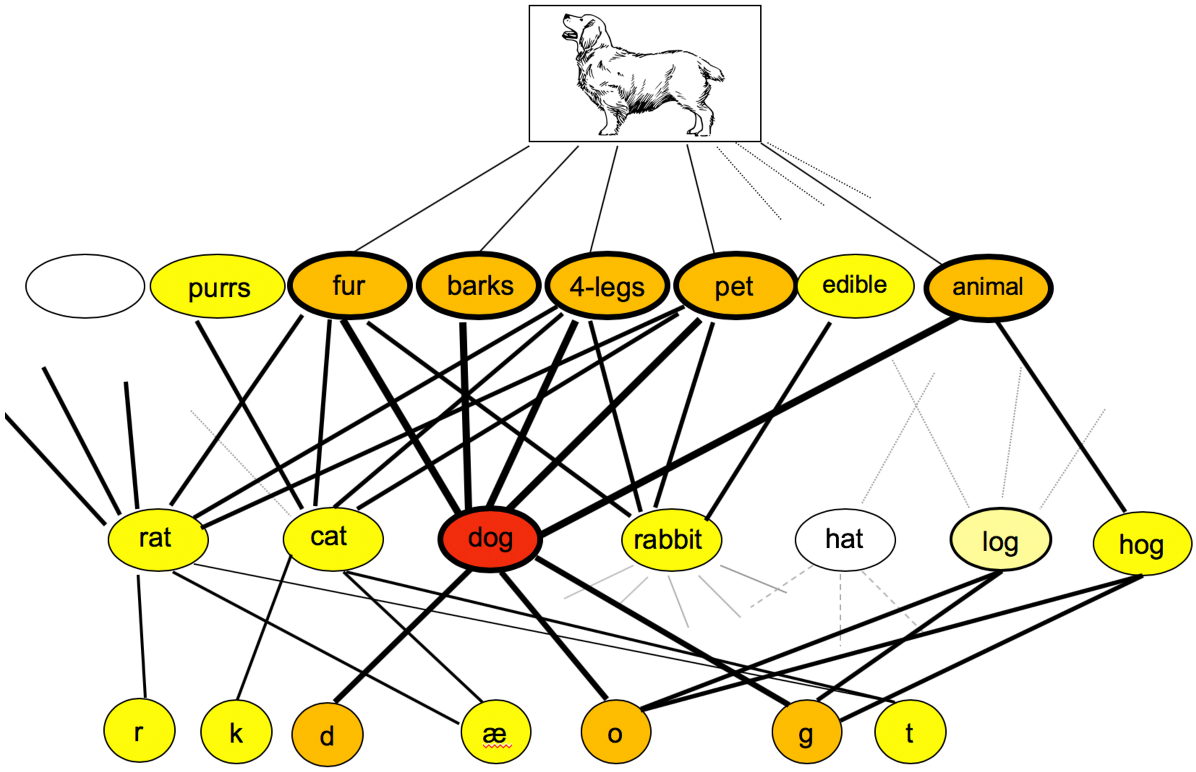

Figure 1. A sketch model of spoken word production derived from those of, for example, Dell & O'Seaghdha (1991), Goldrick & Rapp (2002); Nickels (2001).

Looking in more detail, these phases involve the transformation of conceptual information through three distinct representations of language. Whilst different models use different terms for the phases, in this chapter we will refer to these as: semantic features which are units of meaning rather than the words themselves; lexical units which represent individual abstract words; and phonological units – the individual phonemes that give the language specific sound to the word. The mechanism by which this representational transformation takes place is called spreading activation (e.g., Dell, 1986; Harley, 1984; Roelofs, 1992, 1997; Stemberger, 1985, 1990). During the lexical selection stage, input from the conceptual system activates related semantic feature units in the language system based on the meaning of the concept to be expressed. Multiple features will be activated and this activation will in turn be passed on to all the lexical units they connect to. The most highly activated lexical unit will be the one receiving the most input: the one connected to the greatest number of semantic features. Speech errors at this point in the process will result in incorrect, but semantically-related, words being selected. Activation is, in turn, passed on from the selected lexical units to the phonological units that are required to produce the spoken form. Errors at this phase will result in phonological errors where a correct phoneme is omitted and/or an incorrect phoneme is included.

Beyond a consensus on the broad level of processing and activation flow from concepts to sounds, there is much debate about the precise number and forms of representation and the interaction between the representations and stages of word production. For example, for Levelt, Roelofs and Meyer (1999) competition occurs only within stages. Semantic representations (which are unitary rather than featural) will activate more than the lexical unit but following the selection of the most highly activated unit only this selected lexical unit passes on activation to the phonological phase. For other models, activation of all units cascades down to the next level. In this case, non-selected but semantically related lexical units will also be activated, and they will, in turn, activate their associated phonemes (e.g., Caramazza, 1997; Dell, Schwartz, Martin, Saffran & Gagnon, 1997). This results in more competition and increased opportunities for phonological errors as the phonemes of semantically related words are activated in competition with those of the target word.

Another key difference between models is whether spreading activation flows in only one direction (feedforward) or also flows back up the model. Interactive models of activation (e.g., Dell, 1986; Dell & O'Seaghdha, 1991; Stemberger, 1985) allow for phoneme activation to feedback to lexical units and from lexical units to semantic features. This interaction explains the occurrence of formal errors, where the phonemes activated by the target word feedback activation to other words sharing the phonemes, such as 'log' for 'dog. Mixed errors are also more likely to occur where a real word is produced that is both semantically and phonologically related to the target (such as 'hog' instead of 'dog) as it receives both semantic input and phoneme feedback. A higher than chance rate occurrence of mixed errors has been found in unimpaired individuals (Dell & Reich, 1981; Harley, 1984) and in people with aphasia (Laine & Martin, 1996; Rapp & Goldrick, 2000).

Within most interactive models (e.g., Dell 1986; Dell & O'Seaghdha, 1991; Stemberger, 1985), there are constraints on spreading activation and feedback that facilitates successful word production and limits errors for unimpaired speakers. While selection of a lexical item does not terminate activation of competing items, selection further boosts the activation of the target relative to its competitors (Dell et al., 1997). This boost of activation of the selected lexical unit increases the forward flow of activation from the selected unit to the associated phonemes ensuring that this activation is stronger than any influence of phoneme activation by semantically related words. In addition, the spread of activation is based on the connection strengths between units that have been established from language experience and mastery. This determines the connections and the connection strength between semantic features, between the semantic features and the lexical units, and between the lexical units and phonological form. More frequently used connections will be stronger, enhancing activation flow and increasing the activation of those units to which they are connected. A final constraint in some models is the decay of activation (e.g., Dell et al., 1997; Rapp & Goldrick, 2000). For successful word production, activation must persist long enough for the phonemes of the selected lexical unit to be assembled and produced, and then must quickly return to a natural resting point. In connected speech, this decay must occur quickly enough to not interfere with the production of subsequent words or ideas.

While all speakers make errors in word production, these can be more common within certain populations. For example, older adults report having greater trouble locating the correct word, despite knowing what they want to say (Burke & Laver, 1990; this topic will be covered in Chapter 4). Errors of word retrieval are most common in populations with impairment; including, for example, people with aphasia. As discussed, naming impairments (anomia) in people with aphasia can be of different types. These can usefully be mapped to the stages and processes of word production to better understand the cognitive source of the impairment (Friedmann, Biran & Dotan, 2013). The mechanism of spreading activation is one dimension of potential impairment. A weakening of connections, or the flow of activation between units at any level, will make successful activation more difficult and error prone. Similarly, too rapid a rate of decay of activation will produce high rates of word substitutions and mixed errors as activated phonemes feedback to activate non target words (Martin, Dell, Saffran, & Schwartz, 1994).

Given that anomia can result from a deficit in different stages of lexical retrieval, treatment studies have aimed at targeting the specific deficit (i.e., semantic or phonological), in an attempt to improve the accessibility of the target word (Nickels, 2002b). However, regardless of the locus targeted by the therapy, as noted previously, the treatment tasks very often involve activation of both semantic and phonological representations (Howard, 2000). Therefore, treatment is most likely strengthening the connections between the two levels of representation (Howard, 2000). Consequently, it is difficult to associate treatment of a particular level of representation with a reduction in the impairment at that level. In fact, in a recent study by Meteyard and Bose (2018), they concluded that phonological cueing of picture naming, whilst more effective than semantic cues, were in fact benefiting the early stages of picture recognition, as opposed to phonological retrieval. To date, the research does not allow therapists to accurately predict which type of therapy will benefit which individuals (Hillis, 1993; Nickels & Best, 1996).

Repeated Attempted Naming

One exciting finding is that some people with aphasia may be able to improve their performance in word production simply through repeated attempts at naming without any treatment or feedback. In a single case study, Nickels (2002a) found that for one individual with aphasia, repeated practice of word production tasks, led to improved accuracy despite no input or feedback from the therapist. The individual, JAW, independently completed a task daily for one week, with three different tasks over three separate weeks: spoken picture naming, reading aloud the written word, and delayed copying of the target word (each with different target items). This repeated practice on each of the three tasks significantly improved picture naming. In relation to the repeated spoken naming condition, presentations of a set of pictures and attempts to name them led to significant improvements in accuracy, even though there was no provision of the target name or any feedback on responses. The set of pictures was taken from a pre-tested set and therefore contained words that had been produced correctly twice, incorrectly both times or where JAW had a variable response - one correct and one incorrect naming response.

This variability in accuracy is a feature of aphasia. Howard, Patterson, Franklin, Morton and Orchard-Lisle (1984) found that people with aphasia were consistent overall in the number of items they produced correctly from one session to the next but that different items were accurate. Nickels (2002a) suggested that this variability with sometimes producing the correct word, led to gradually increased accessibility of the target words after multiple attempts at naming. Furthermore, when the correct target is selected, it is hypothesised to strengthen the connections between the semantic and phonological form (i.e., repetition priming, see below for further discussion). If the correct name is required to be successfully produced in order for this strengthening to occur, then there must be enough presentations for the correct name to be produced, and subsequently primed. However, it is also possible that simply attempting to name the item (even when not produced) will activate the relevant semantic and lexical nodes sufficiently and increase the chances of successful retrieval on the next attempt. This assumes that incorrect responses will not also be reinforced and increase the likelihood of an error. These possibilities will be discussed in Chapters 2 (Paper 1) and 5 (Paper 4). This attempted naming effect is important, not just as a potential form of treatment, but because repeatedly naming a target word in the presence of a picture, is a common component of major therapies for aphasia. So if repetition enhances performance, then a portion of the effectiveness of treatments, may be attributable to just this repetition. It has been suggested that the mechanism underlying repeated naming and treatment effects could be the same (Nickels, 2002b). This association is explored in Chapter 2 (Paper 1).

Repetition Priming

Repetition priming refers to the finding that an individual's ability to perform a task is improved if they have already experienced that item in the context of the same or a related task. For example, previous repetition of a target word can improve success in a subsequent picture naming task for people with aphasia (Howard, Patterson, Franklin, Orchard-Lisle & Morton, 1985). The concept of priming in treatment of anomia is not a novel concept. Weigl's (1961) de-blocking technique involved taking advantage of a less impaired modality to allow the individual to successfully produce the target in one context (cited in Howard et al., 1985). The idea being that when presented with the item again in the impaired modality, the item will be 'de-blocked' and more likely to be produced. For example, if the individual displayed spared repetition, but impaired picture naming, having them repeat the name should improve their subsequent naming. Weigl suggested that this was a short-lived advantage (less than ten minutes) but if successfully produced within that timeframe, could last up to two years (Weigl, 1961, cited in Howard et al., 1985). Production of the target primes it and improves production in the impaired modality.

Priming of word retrieval also has a robust effect in unimpaired speakers. This has been demonstrated in repetition priming studies of word production. For example, when presented with a phonologically-related auditory prime (e.g., *dot*) prior to naming a picture of the target (e.g., *dog*), participants were significantly faster at naming the target pictures (Jescheniak & Schriefers, 2001; Kurtz, Schriefers, Mädebach and Jescheniak, 2018).

The focus of this thesis is on priming observed in word retrieval through the use of a picture naming task. The single repeat presentation of a picture for naming has been shown to significantly reduce individuals' response times over both short and longer time periods. Within a single session, unimpaired speakers show strong priming effects (e.g., Brown, Jones & Mitchell, 1996; Durso & Johnson, 1977; Wiggs, Weisberg & Martin, 2006). Repetition priming has also been found at much longer delays, even 48 weeks after the initial presentation (Cave, 1997).

Generally, in psycholinguistics, people attribute this improvement from repetition to priming effects within the language system. By successfully selecting, retrieving and producing the target word the first time it becomes more accessible either through temporarily changing the activation levels or by incremental learning - changing the connection weights (see Oppenheim, Dell & Schwartz, 2010 for discussion), or in, for example, Morton's Logogen model, a lowering of the activation threshold for a target (Morton, 1969).

An alternative mechanism proposed to underpin repetition priming is through episodic memory: remembering the previous attempt and the response made to the same picture. Whilst this is a potential explanation for those studies (the majority of) that use identical pictures at both naming events, this cannot be the full picture. Studies of priming in the short term have examined using a different prime and probe. For example, Wheeldon and Monsell (1992) used word definitions as the initial prime. Whilst the magnitude of priming was lower compared to studies using identical pictures, priming remained significant. Furthermore, amnesic patients can show normal priming effects, even though they have no recollection of the priming event (Cave & Squire, 1992). Hence, whilst priming may be a form of implicit memory, it appears to be dissociable from explicit memory. In longer term studies (e.g., Cave, 1997; Mitchell & Brown, 1988), priming was not associated with recognition of the pictures. Nevertheless, it is possible that some implicit visual memory of the pictures has occurred and this cannot be ruled out given that all the long term studies of priming of picture naming use identical pictures. Hence, priming effects may stem, at least in part, from speeded visual identification as opposed to speeded word retrieval. Therefore, whether priming of word retrieval really does last long term, remains unanswered. This limitation of previous studies will be discussed further in Chapter 3. Furthermore, this will be addressed in experiments in Chapters 3-5, by using different exemplars of items, to minimise visual effects contributing to priming effects.

Localisation of Priming

Given the evidence for priming effects in word production, the question remains as to what point in the word production process this facilitation occurs. Wheeldon and Monsell (1992) attempted to pinpoint this by replacing the prime (naming of a word definition) with a semantically unrelated homophone (i.e. a word that sounds the same, but means something different, e.g., son for sun). This condition, where the word form but not the meaning was shared between prime and target, resulted in no significant priming. The authors suggest that as the repetition of the word form is not sufficient for priming in word production, priming requires the activation of the semantic features of words and the mapping of these semantic units to the lexical units (Wheeldon & Monsell, 1992). This finding appears to rule out the phonological phase as the locus of priming. Beyond this, it remains difficult to separate the lexical phase, or the mapping between semantics and lexical units, or from lexical to phonological form as the likely locus of priming effects. Indeed, different authors have suggested different loci, for example, Howard et al. (2006) suggested that the most likely stage in the word retrieval process for repetition priming to occur was in the mapping from semantics to lexical units. While Wheeldon and Monsell (1994) argued that since the effect was more durable than semantic interference (thought to occur from semantics to lexical units), that repetition priming strengthened the mapping from the lexical representation to the phonological form (but not from repetition of the phonology alone).

Of course, this assumes that all individuals benefit from repeated attempts at naming/repetition priming due to facilitation at the same level of processing. As discussed earlier, different populations can make different speech errors and may have weaker connections between levels of the word retrieval process. For example, older adults often make more naming errors and are slower to retrieve words compared to young adults (Burke, MacKay, Worthley & Wade, 1991; Mitchell, 1989; Nicholas, Obler, Albert & Goodglass, 1985). It has been proposed that older adults have weakened connections to phonological units (for review see Shafto & Taylor, 2014). Therefore, if repetition priming can help strengthen access to phonology from semantics, it may be more beneficial for older adults compared to young adults. While previous studies have explored this, contrasting results means that this remains unanswered (e.g., Mitchell, Brown & Murphy, 1990; Wiggs et al., 2006). This possibility of age-related effects of priming will be explored in Chapter 4 (Paper 3). Similarly, people with aphasia, who can have deficits at different phases in word retrieval, may also show larger priming benefits compared to young adults with no language impairments. Or conversely, it may be that certain additional language or cognitive skills are required in order to show intact priming, which perhaps are impaired in some individuals with impairment.

Indeed, one aspect which seems to be neglected in the unimpaired priming literature is whether priming is present for all unimpaired speakers. All previous studies examine priming (in people without language impairment) at the group level. However, attempting to locate the timepoint in word retrieval which priming occurs using only group data, assumes that all individuals show the same priming effects. Individual variability in priming will be explored in Chapters 4 (Paper 3) and 5 (Paper 4) of this thesis. It is possible that repetition priming is the result of more than one mechanism which may interact differently with different individuals. Examining different populations and taking a closer look at individual differences can help uncover this possibility.

Cumulative Priming Effects

Another dimension of repetition priming is the effect of multiple repetitions on the strength and durability of priming. This has not been widely examined for unimpaired subjects. In a study using phonological priming of picture naming, Kurtz, Schriefers, Mädebach and Jescheniak, (2018) found the largest priming effects at the first repetition, however, participants continued to get faster across the session with additional attempts. Similarly, Gollan, Montoya, Fennema-Notestine and Morris (2005) found decreasing response times from the second to the fifth repetition of a target in a picture naming task, once again the biggest effect was for the first repetition. Wiggs et al. (2006) found significantly larger priming following three repetitions compared to one. However, this additional benefit had disappeared by a delay of one month. In a study comparing single or multiple repeated attempts, MacDonald et al. (2015) found that unimpaired speakers showed significant priming on response latencies in both the single repetition within a session, and with six repeats over two days. In contrast, in the same set of experiments, individuals with aphasia, only produced significant priming effects on latency in the longer term condition with multiple repetitions (Heath et al., 2015). However, given that the number of repetitions were also confounded with the time lag between prime and testing, it is difficult to conclude that the significant priming was only due to multiple repetitions. In aphasia studies, while there is some evidence that facilitation can occur after a single repetition for some individuals with aphasia (Howard, 2000; Nickels, 2002a, 2002b), multiple repetitions are almost always provided. To conclude, there is mixed evidence in regard to the benefits of multiple repetitions.

Preview of the thesis

The overall aim of this thesis is to help further understand the mechanisms underlying improvements in word retrieval following treatment for anomia with people with aphasia. The thesis explores improvement of word production through the use of repetition priming for both unimpaired speakers and people with aphasia. It is presented as experimental chapters that are written in the format of (to-be-submitted) journal articles. Consequently, there is some repetition of literature and content through the thesis chapters, and within each chapter the other thesis chapters are referred to as (in preparation) journal articles.

Chapter 2 (Paper 1) aims to extend the findings of Nickels 2002a, to determine the extent to which people with aphasia can improve their word retrieval through repeated naming attempts, with no feedback or treatment. This study also investigates whether there are any language and wider cognitive abilities associated with improvements as a result of attempted naming.

As discussed above, the mechanism underpinning improvement from attempted naming in people with aphasia has been hypothesised to be the same as repetition priming. The subsequent papers explore the time course of repetition priming in unimpaired speakers (both young and older) and in people with aphasia. As was discussed, previous studies looking at longer term repetition priming (beyond two days), all used identical pictures. This makes it hard to disentangle priming of word retrieval and priming of picture identification. Therefore, all priming experiments in this thesis use different exemplars of items to attempt to minimise any visual effects inflating the amount of priming. These are the first experiments to look at the time course of repetition priming with different exemplars.

Chapter 3 (Paper 2) focuses on the time course of repetition priming in unimpaired young adults using different exemplars. When minimising visual priming, is repetition priming of word retrieval as long lasting as previous studies suggest? Experiment 1 examines the time course across one week. Experiment 2 extends this, examining lags up to four weeks. Both experiments also investigate cumulative priming effects to see if there is any additional benefit from including extra presentations.

Chapter 4 (Paper 3) used the same experimental design and methods as Experiment 1 in Chapter 3, this time with older adults. The aim of this study was to see if there are any age-related effects on priming. Word retrieval can become slower and more error prone with age. But do older adults show age-related differences in priming of word retrieval? Priming was also examined at the individual level to see if effects are really as robust as group results suggest. Given that clinicians would benefit from determining whether priming is 'intact' in individual people with aphasia, it is important to determine whether all unimpaired individuals show priming.

Chapter 5 (Paper 4) aims to uncover how robust repetition priming is for people with aphasia. Given that these individuals have deficits in the process of retrieving words, do they also have deficits in the extent of their ability to be primed? This is explored at the group and individual level, and the chapter investigates whether any specific cognitive and language skills are required for priming to occur.

Finally, Chapter 6, the General Discussion, summarises all of the findings in this thesis and the implications for treatment of anomia. Methodological issues such as type of analysis and statistical power are reflected on as well as possible directions for future research.

It is hoped that by better understanding repetition priming effects in normal and impaired speakers, at both the group and individual level, this thesis will equip us better to develop appropriate and individualised treatments for people with aphasia.

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Chapter 2 (Paper 1)

Name it Again. Improvements from repeated naming attempts in aphasia

Abstract

In the context of therapy for word retrieval in aphasia, the person with aphasia is often required to attempt to name treated items on multiple occasions. However, there is limited information about the impact of these repeated attempts at naming in and of themselves. The aim of this study was to examine if repeated attempts at naming, with no treatment or feedback, improve naming accuracy in people with aphasia.

23 participants with stroke aphasia named 50 pictures on seven occasions, approximately six weeks apart. No treatment or feedback on accuracy was provided. This was part of a larger study investigating two different types of therapy on different items.

After excluding any potential influence from treatment of other items, four participants showed significant improvements in accuracy and two participants showed a worsening of accuracy for the stimuli that received repeated naming attempts (but were untreated).

We found evidence that significant change in accuracy was associated with variability of naming accuracy between sessions. Intact executive functioning skills (as measured by the Wisconsin Card Sorting Task), correlated with an increase in accuracy. We hypothesised intact executive functioning may help monitor responses, such that only correctly named items are reinforced. Critically, without the ability to monitor responses without feedback, incorrect responses may be reinforced, leading to a worsening of performance.

The fact that four individuals with aphasia showed improved naming accuracy by naming items once every six weeks is striking and suggests that further investigation of effects of repeated naming at closer intervals is warranted, as for some participants any advantage from a naming attempt may have decayed by the time of repetition.

Introduction

Anomia, a difficulty in retrieving and producing words, is a distressing problem affecting most people with aphasia, which causes ongoing difficulties for everyday communication and interaction (Best et al., 2013). While interventions have demonstrated significant performance improvements (Wisenburn & Mahoney, 2009), it remains a complex and difficult aspect of aphasia to treat. Individuals with anomia may have varying degrees of deficit across all or some of the cognitive processes involved in spoken word production, such as accessing word meaning, the retrieval of the word form, or the assembly of phonemes. Much of the focus of treatment studies has centred around each component of word retrieval and matching them to an individual's particular deficit profile (Nickels, 2002b; Best et al., 2013). One intriguing possibility is that, for some individuals, word retrieval can improve without direct treatment but simply by repeatedly attempting to naming (Nickels 2002a). It is this finding of improvement in naming through repeated retrieval attempts that is the focus of the current study, which explores the role of such practice on performance improvement in word production in a case series of individuals with aphasia.

A substantial number of treatment studies have demonstrated that word retrieval performance can be improved with therapy, using a wide variety of treatment methods (for review see, e.g., Nickels, 2002b; Wisenburn & Mahoney, 2009). Most commonly these improvements are restricted to the production of the treated items themselves, rather than leading to general improvements in word retrieval and production ability (see Best et al., 2013). This suggests that the repeated activation of the semantic and phonological representations of specific target words, either individually or in combination, is usually necessary for performance gains. Despite different treatments focusing on semantic or phonological enrichment, orthographic or phonological cueing, the successful production of the target word involves the activation of all components of the word production system and improvement has been suggested to be driven by priming the mapping of semantic and phonological form of a given word (Howard, Hickin, Redmond, Clark & Best, 2006; Nickels, 2002b).

Some studies have identified treatment improvements extending to untreated items and considered these to be *generalisation* of treatment effects (see Best et al., 2013; Nickels, 2002b; Webster, Whitworth & Morris, 2015). So clearly priming retrieval of specific words may not be the only mechanism underpinning treatment effects. However, control items may be repeatedly tested through a treatment study and the process of testing may itself generate improvement for some individuals (Nickels, 2002a), which may be (mis)interpreted as generalisation.

Clear evidence of performance improvements as a result of practice rather than treatment, comes from a single case study where an individual with aphasia, JAW, who showed accuracy gains from practicing word production tasks without any correction or input from the therapist (Nickels, 2002a). Three tasks were used: a spoken task involving attempting to name the picture, a written task involving reading aloud the written form of the target word and a writing task involving delayed copying of the name of the picture. In each of these conditions JAW showed significant improvement in his ability to correctly produce the target words in response to a picture.

A key feature of anomia is that there is variability in accuracy of word retrieval so that the same picture may sometimes be named correctly and sometimes incorrectly (Howard, Patterson, Franklin, Morton, & Orchard-Lisle, 1984). It is hypothesised that when a correct word is produced, and the semantic and phonological forms are both activated, it increases the likelihood of producing the correct word on a subsequent attempt as it strengthens the mapping between the semantic representation and the phonological form (Howard, 2000; Miceli, Amitrano, Capasso & Caramazza, 1996; Nickels, 2002a, 2002b). Nickels (2002a) concluded that this ‘repetition priming’ could underpin JAW’s results; successfully activating the target word in prior attempts resulted in a strengthening of the mapping from the semantic representation to the phonological form for the target words and thereby improved subsequent retrieval success (Nickels, 2002a).

If a correct naming response is required to boost subsequent performance, then it follows that the untreated items must be presented enough times for a successful naming event to occur. However, it is possible that even if the incorrect word form is retrieved, simply attempting to name a picture will activate relevant lexical and semantic nodes sufficiently to decrease the demands of processing the picture a second time and increase the likelihood of producing the correct word. Critically, this explanation assumes that incorrect responses will not be primed to the same extent as correct responses. That errors do not impair response to treatment is supported by studies that have contrasted the effects of errorful and errorless treatment approaches in anomia. Errorless learning attempts to minimise the chance that participants can say the wrong response, by presenting the target to produce (sometimes both auditorily and visually; e.g., Abel, Schultz, Radermacher, Willmes & Huber, 2005; Fillingham, Sage & Lambon Ralph, 2005a). Abel et al. (2005) compared errorless (decreasing) cueing (where all the cues are included in the initial presentation of a picture to support correct word production, and are slowly removed after a period of learning) with traditional cueing for a group of 10 people with aphasia in a picture naming task. They found that errorless cueing did not result in a greater benefit for subsequent naming as would be predicted (see also, Fillingham et al., 2005a). Nevertheless, Fillingham, Lambon Ralph and colleagues have claimed that non-language based cognitive processes, such as executive control, monitoring and/or recognition memory skills, are involved in an individual's ability to benefit from a particular treatment (e.g., Fillingham, Sage & Lambon Ralph, 2005a; 2005b; 2006; but see Morris, Howard & Buerk, 2014). Fillingham et al. suggest that these control processes may be critical in preventing erroneous responses being primed.

While we are not aware of any subsequent study that has focused directly on the effects of unaided attempted naming on performance in aphasia, there is increasing evidence that JAW's pattern was not unique. For example, Wambaugh and Ferguson (2007) included an untreated condition which was named (without feedback or provision of the target[1]) as often as the treated stimuli, and found that this set showed improvement over the course of the study. In contrast a set which was only probed before and after treatment showed no gains.

For individuals with unimpaired language production, there is considerable evidence that attempts at naming improves performance: Having named a picture once previously has been reliably shown to significantly reduce response times (e.g., Durso & Johnson, 1979; MacDonald et al., 2015; Mitchell & Brown, 1988). Furthermore, this effect is long lasting, with significant response time reductions found at six weeks (Mitchell & Brown, 1988) and up to 48 weeks (Cave, 1997) after initial presentation. For individuals with aphasia, limited research has examined effects of repetition priming but such research that there is (e.g., Creet, Morris, Robidoux, Howard & Nickels, 2018; Soni, Lambon Ralph & Woollams, 2012), suggests that there can be effects on naming latencies.

In the current study, performance of people with aphasia on a picture naming task was examined over time, in order to further examine the occurrence of effects of attempted naming on performance. The data involved untreated items which were assessed as part of a wider study by Morris et al. (2014). Their study investigated the effects of two prominent therapies, Semantic Feature Analysis (SFA: Boyle, 2004) and Repetition in the Presence of a Picture (RIPP: Mason et al., 2011) using a comparatively large subject group of 23 individuals with aphasia. It included seven different time points at which picture naming of both treated and untreated items was assessed. The focus of the current study was the pattern of performance in naming of the untreated items and whether repeated attempts at naming can

[1] Note it is important to distinguish studies where naming attempts do not receive feedback, nor provision of the correct response, from those, such as Off, Griffin, Spencer & Rogers (2016), where although feedback is not provided, the correct target is. Or Wingfield, Brownell & Hoyte (2006) who provide correction. We focus on the former condition, with no feedback or correction.

lead to performance improvements without any treatment or feedback; specifically, whether participants with aphasia show improvements from repeated attempted naming.

Secondly, assuming that performance effects can be demonstrated, the study examines whether there is a relationship between an individual's response to attempted naming and their response to treatment. It has been hypothesised that a key mechanism underlying treatment effects is the strengthening of the link between a word's meaning and phonological form (Heath et al., 2015; Howard, 2000; Miceli et al., 1996; Nickels, 2002b). This same mechanism has been proposed to underpin improvement from repeated attempted naming (Nickels, 2002a), consequently an association is predicted between treatment-related and attempted naming-related improvements.

Finally, this study investigated whether there were any predictors of improvements as a result of attempted naming. Potential predictors include language and wider cognitive abilities of an individual, and the extent of variability in performance.

Method

Participants

Participants were 23 individuals with aphasia (20 male, 3 female), who had all suffered a single left hemisphere symptomatic stroke at least four months prior to commencing the study. Participants were aged between 36 and 82 (M = 68, SD = 11.5). All participants had normal or corrected-normal hearing and vision. Participants had no premorbid history of learning difficulties, no severe apraxia of speech, and all displayed some naming difficulties. See Table 1 for demographic information about the participants.

Language and Wider Cognitive Profile

The effects of therapy may vary across participants as a result of their language and wider cognitive profile. To investigate whether the level or type of deficit was linked to any improvement in naming, for each PWA, the following assessments were completed to develop a profile of their impairment:

1. General Aphasia Severity
   - Western Aphasia Battery - Revised (WAB - R, Kertesz, 2006): Aphasia Quotient (AQ)
2. Comprehension
   - Psycholinguistic Assessment of Language Processing in Aphasia (PALPA) spoken word to picture matching (Kay, Lesser, & Coltheart, 1992)
   - PALPA written word to picture matching
   - PALPA auditory synonym judgement
   - Pyramids and Palm Trees (3 picture version) (Howard & Patterson, 1992)
3. Spoken output
   - Nickels Naming Test (Nickels & Howard, 1994, 60 items from the original set of 130, balanced across conditions)
   - Reading aloud (words/nonwords) (unpublished set which varies in length, frequency and imageability)
   - Repetition (words/nonwords) (unpublished set which varies in length, frequency and imageability)
   - Apraxia of Speech Screening (informal screening based on principles from Duffy, 2005)
   - Word Fluency (animals and s-words per minute) from the Comprehensive Aphasia Test (CAT; Swinburn, Porter & Howard, 2004)
4. Other Cognitive Assessments
   - Modified Wisconsin Card Sorting Task (Schretlen, 2010)

- Recognition Memory (CAT; Swinburn et al., 2004)

Table 1
Participants' demographic information and aphasia severity scores.

Participant	Age	TPO (months)	Gender	Years of Education	WAB - AQ	WAB aphasia classification
P21	74	13	M	11	50	Broca
P25	67	5	M	12	90	Anomic
P22	51	11	M	13	82	Anomic
P11	64	17	M	14	75	Conduction
P4	68	20	M	13	63	Broca
P3	70	46	M	11	84	Conduction
P23	75	120	M	13	80	Anomic
P7	73	24	M	11	37	Broca
P2	64	36	M	11	70	Conduction
P18	82	5	M	13	83	Anomic
P6	52	6	M	11	23	Broca
P5	71	32	M	12	66	Conduction
P10	36	34	F	11	76	Anomic
P20	65	51	F	13	76	Conduction
P14	61	4	M	10	60	Wernicke
P13	58	18	M	14	28	Broca
P8	61	82	M	13	53	Broca
P12	80	6	F	12	44	Broca
P1	81	11	M	11	66	Anomic
P19	74	67	M	13	73	Broca
P24	81	14	M	13	31	Broca
P15	81	5	M	10	76	Anomic
P17	78	9	M	13	69	Anomic

Note: Data from 23 individuals are reported in this study. However, two further participants (P9 & P16) were recruited to the main study but did not complete all assessments. Participants are therefore labelled P1 to P25. For consistency across data reporting, participants are ordered based on their average increased accuracy for the untreated items (see later), from most to least improvement.

Materials

Three matched sets of 50 coloured photographs, each depicting a noun on a white background, were sourced from Hemera Photo Object Library (Hemera Technologies Inc, 1997-2000). The sets were created using an individual's naming accuracy from the first two assessments (so unique for each participant). The number of successfully and unsuccessfully produced responses from the two initial assessments was matched and then each group was balanced for word variables such as frequency and length (see Morris, Howard & Buerk, 2014 for a more detailed description of the method).

These three sets were assigned to three conditions:

1. Semantic Feature Analysis (SFA) therapy.
2. Repetition in the Presence of a Picture (RIPP) therapy
3. Untreated (used only in assessment).

Design and Procedure

Participants named 150 pictures on seven occasions (see table 2). Therapy periods were between assessments 2 and 3 and between assessments 4 and 5. Each therapy period was six weeks with two therapy sessions per week, each session lasting 45 mins. One of the therapy periods consisted of Semantic Feature Analysis and the other Repetition In the Presence of a Picture, with people with aphasia randomly assigned to either have Semantic Feature Analysis in the first period and Repetition In the Presence of a Picture in the second, or in the reversed order. The 50 untreated items, which are the focus of this study, were not treated or exposed in any way between assessments. Each untreated item was presented a total of seven times. The assessment was always of the 150 items, with treated and untreated items interspersed in a random order. Participants were required to name all 150 items, with no feedback provided. The assessments were spaced approximately 6 weeks apart, except for the final assessment, which was approximately 10 weeks later.

Table 2

Picture Naming Procedure

Assessment Points for all 150 items (approximately six week intervals)						
1	2	3	4	5	6	7
	→		→			
	Treatment Phase 1 (either SFA or RIPP)		Treatment Phase 2 (either SFA or RIPP)			

Note: SFA = Semantic Feature Analysis; RIPP = Repetition In the Presence of a Picture

Response scoring

A response was recorded as correct if the correct noun was initiated within five seconds of presentation. Only the first response was scored, regardless of whether the participant self-corrected an error. Minimal fillers prior to a response such as 'umm' or 'ahh' were allowed but any attempt to articulate a word was taken as their response e.g., "ra…cat" for *cat* would be scored as incorrect.

Analysis 1: Effects of repeated attempts at naming

This analysis explored whether attempting to name an item without any treatment or feedback led to performance improvements on those items by analysing individuals' pattern of naming accuracy of the untreated items across the seven assessment sessions.

Method

WEighted STatistics (WEST: Howard, Best & Nickels, 2015) were used to evaluate whether there was any trend in naming (WEST-Trend). This approach allows weightings to be assigned to multiple assessment points, to create a value that indicates the overall trend of the assessments over time. Given that the seven assessments were spaced by approximately six weeks each and no treatment was conducted on these items, a linear trend was fitted. Therefore, the weighted scores were calculated using the coefficients -3, -2, -1, 0, 1, 2, 3 for each of the seven assessment points. These coefficients were multiplied by the accuracy (0 or 1) for each item for each individual. These weighted scores were then summed for each item to create the overall improvement trend for an item; a positive value indicated a positive trend (improvement) across the seven assessment points. A negative value indicated a negative trend (worsening of performance). To look at the overall improvement for each participant, one-sample *t*-tests (two-tailed) were calculated using these summed weighted accuracy scores for the improvement trend for each item. Homogeneity tests were also conducted to examine whether there was evidence for differences in performance across participants.

In order to consider whether any significant changes in accuracy occurred solely due to the repeated presentation of the items, rather than being a result of treatment-related generalisation processes, we performed additional analyses for participants who showed significant WEST-TREND. To do this we used WEST-Rate of Change (WEST-ROC; Howard et al., 2015) which compares the rate of change in accuracy between treated and untreated periods. We used the same weights as in the main treatment study and carried out three analyses, one comparing rate of change during phase 1 of treatment, with all other phases, one for phase 2 of treatment versus all other phases, and one comparing both treatment phases versus phases without treatment (see Appendix A for the weights used). A one-sample *t*-test was then conducted using the weighted scores.

Results

Four of the individuals showed a significant positive trend in their naming of the untreated items across the seven assessment points (participants 11, 21, 22 and 25). However, unexpectedly, a further four individuals showed a significant negative trend: participants 12, 15, 17, and 24 (see Table 3).

Table 3

The proportion of items correctly named (n=50) for untreated items at each assessment point by each participant, and results of WEST-TREND analysis.

Participant	Average proportion of items gained per assessment	Proportion of items Correct at each assessment							One sample t-value	2-tailed p
		1	2	3	4	5	6	7		
P21*	.039	.26	.34	.36	.26	.40	.36	.60	3.634	**.001**
P25*	.025	.40	.44	.50	.36	.46	.66	.50	3.033	**.004**
P22*	.025	.54	.46	.54	.62	.60	.66	.62	2.312	**.025**
P11*	.023	.38	.50	.60	.46	.54	.64	.52	2.109	**.040**
P4	.017	.40	.24	.34	.34	.46	.42	.40	1.875	.067
P3	.015	.54	.40	.46	.46	.60	.48	.58	1.265	.212
P23	.013	.38	.50	.42	.52	.52	.48	.48	1.019	.313
P7	.011	.32	.28	.34	.34	.34	.34	.38	1.076	.287
P2	.010	.16	.06	.08	.20	.14	.08	.22	1.171	.247
P18	.009	.46	.52	.44	.48	.52	.46	.56	.872	.387
P6	.003	.02	.06	.08	.04	0	.08	.06	.531	.598
P5	.001	.46	.42	.44	.50	.36	.48	.46	.184	.855
P10	-.004	.44	.48	.44	.40	.48	.40	.44	-.346	.731
P20	-.005	.44	.44	.48	.50	.42	.34	.48	-.442	.661
P14	-.006	.44	.40	.38	.38	.40	.40	.38	-.565	.575
P13	-.009	.14	.12	.12	.10	.10	.06	.10	-1.187	.241
P8	-.009	.26	.26	.46	.28	.30	.24	.24	-1.066	.291
P12*	-.009	.12	.10	.08	.08	.06	.04	.08	-2.098	**.041**
P1	-.011	.16	.18	.14	.20	.12	.10	.12	-1.744	.087
P19	-.019	.54	.52	.52	.52	.54	.54	.34	-1.809	.077
P24*	-.021	.22	.18	.20	.12	.10	.14	.08	-2.393	**.021**
P15*	-.034	.50	.38	.22	.24	.38	.28	.20	-3.351	**.002**
P17*	-.039	.32	.46	.30	.28	.16	.22	.16	-4.409	**.000**

NOTE: Participants are ordered based on the size of average improvement between each assessment point. Participants who showed significant WEST-Trend are highlighted in bold.

Combined across all participants, the average change in accuracy was slight, with an average of just .001 per assessment session, which was not significant (z =.026, p = .979, two tailed). However, the homogeneity test was highly significant (χ^2 (22) = 83.55, p<.0001), indicating that there was variation in the patterns shown across participants. The mean change in number of items named successfully between consecutive assessments for each participant in Figure 1, illustrates this large variation.

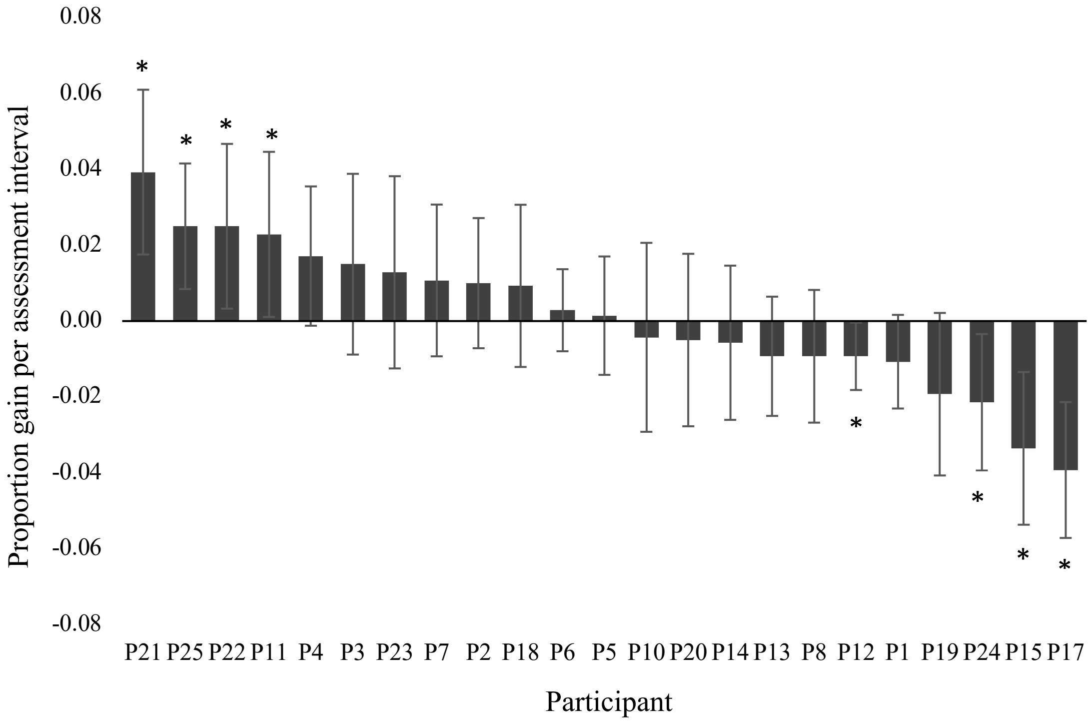

Figure 1. *Improvement trends for the untreated items with 95% confidence intervals. Asterisks indicate statistical significance.*

For the 8 individuals who showed significant effects, we tested whether these changes in accuracy occurred solely due to the repeated presentation of the items and not generalisation or interference effects from treatment using WEST-ROC. None of the four individuals who showed a positive trend across the study showed any evidence of significantly different rate of change across treated and untreated phases. However, P15, one of the four participants who showed a negative trend, showed significant treatment-related *improvement* in the second treatment phase (Repetition in the Presence of the Picture treatment) and, close to significant, treatment-related *decline* in the first treatment phase (Semantic Feature Analysis; see Table 4 below). Participant P17 was close to showing significantly greater *decline* in the treatment than no treatment phases. These two participants will therefore be excluded from further analysis.

Table 4

Results of 1-sample t-tests conducted for each of the 8 individuals who had significant change in accuracy on untreated items across the sessions.

Ppt	Trend across the whole study period (WEST-Trend)		Greater change during therapy than no therapy phases (WEST-ROC)		Greater change during therapy phase 1 (WEST-ROC)		Greater change during therapy phase 2 (WEST-ROC)	
	t(49)	p 2-tailed	t(49)	p 2-tailed	t(49)	p 2-tailed	t(49)	p 2-tailed
Significant Improvement								
21	3.63	**.001**	-.87	.388	-1.47	.147	.55	.587
25	3.03	**.004**	.89	.378	-.40	.378	1.28	.207
22	2.31	**.025**	.65	.522	.62	.535	-.03	.973
11	2.11	**.040**	1.46	.152	1.3	.199	.09	.925
Significant Worsening								
12	-2.1	**.041**	-.68	.502	-.52	.608	-.17	.863
24	-2.39	**.021**	.29	.773	.15	.880	.14	.888
15	-3.35	**.002**	.90	.370	*-2*	*.051*	3.49	**.001**
17	-4.41	**.000**	*-1.93*	*.060*	-1.02	.313	-1.19	.239

Discussion

For eight of the 23 participants, there was significant change across the study in picture naming accuracy for items that were named every six weeks but received no treatment. However, after excluding any potential influence from treatment (analysed using WEST-ROC), four of the 23 participants showed significant improvements in accuracy and two participants showed worsening accuracy across the study. Decline in performance was an unexpected but nonetheless interesting result. One of the participants, P12, performed almost at floor throughout the assessments. While her decline was significant, in absolute terms it was very small (.009 per session, .49 items). P24 showed somewhat better performance and steady decline. One possible cause of this decline is that the errors produced could have been primed, leading it to be more likely to produce this same incorrect response on a subsequent occasion. We will return to this point in the General Discussion.

Importantly, we have replicated Nickels (2002a) results demonstrating that some (albeit a small proportion) of people with aphasia can benefit from repeated attempts at naming in the absence of feedback. What remains to be identified is why there was significant variability in the patterns observed, with some individuals improving and some declining (and others showing no significant change). It is possible that a prerequisite for beneficial attempted naming effects is to start from a level of being able to sometimes, but not always, produce the correct response. If an individual's responses are seldom correct, then there will be little opportunity for priming effects. If an individual's responses are usually correct (near ceiling), then there will also be little opportunity for improvement. This will be explored below.

Analysis 2: Relationship between benefits from repeated attempts at naming and response to treatment

If the mechanisms underlying any improvements as a result of either repeated naming or treatment are the same, such as repetition priming, then the amount of improvement shown on the untreated items over these seven sessions should correlate with the amount of improvement on treated items that was observed as a result of treatment: those people who show more treatment-related gains should show more improvement from repeated attempted naming.

Method

Pearson's correlations were conducted across all participants to examine the relationship between any improvement as a result of treatment and the trend for any improvements as a result of repeated attempted naming. The effects of repeated naming attempts were measured using the trends for untreated items calculated from the WEST-Trend analyses discussed above. The effects of treatment on the treated items were measured using the weights for treated items in the WEST_ROC analyses (representing the extent of treatment-related gains) for each phase of treatment independently (SFA, RIPP) and over both phases combined (SFA & RIPP).

Results

Looking at the two types of treatment (regardless of treatment order), there was a significant correlation between change in the untreated items (WEST-TREND) and benefit from treatment (WEST-ROC) with Semantic Feature Analysis ($r(23) = .438$, $p = .018$) but only marginally with Repetition in the Presence of a Picture ($r(23) = .311$, $p = .074$) and both treatment phases ($r(23) = .297$, $p = .084$). The two treatments were correlated with each other ($r(23) = .561$, $p = .003$). However, the correlations between change in untreated items and the different types of treatment were not significantly different to each other (Fisher r-to-z transformation, z = .47, p =.64, two-tailed). Similarly, the Bayes factors for these correlations between improvement in untreated items and treatment improvement indicated that there was no strong evidence supporting either a relationship between the two measures, nor, conversely, supporting no relationship (all Bayes factors between .33 and 3: SFA: BF10 = 2.04; RIPP: BF10 = .69; GDT: BF10 = .63).

Looking at the six individuals who showed significant change in the untreated items, Figure 2 shows the pattern of correct responses for each of the three conditions (untreated, SFA, RIPP) across the study. Of the four individuals who showed significant improvement as a result of repeated attempts at naming, all four showed significant improvement trends for the treated items (see Table 5). Three (P11, P22, P25) also showed a significant treatment-related response to at least the RIPP phase of treatment (significant WEST-ROC). Participant 21 showed no evidence of treatment-related improvement. Neither of the two participants who showed a significant decrease in accuracy for the untreated items showed significant treatment-related improvement (WEST-ROC), although P24 showed a significant negative trend for the treated items as well as the untreated items.

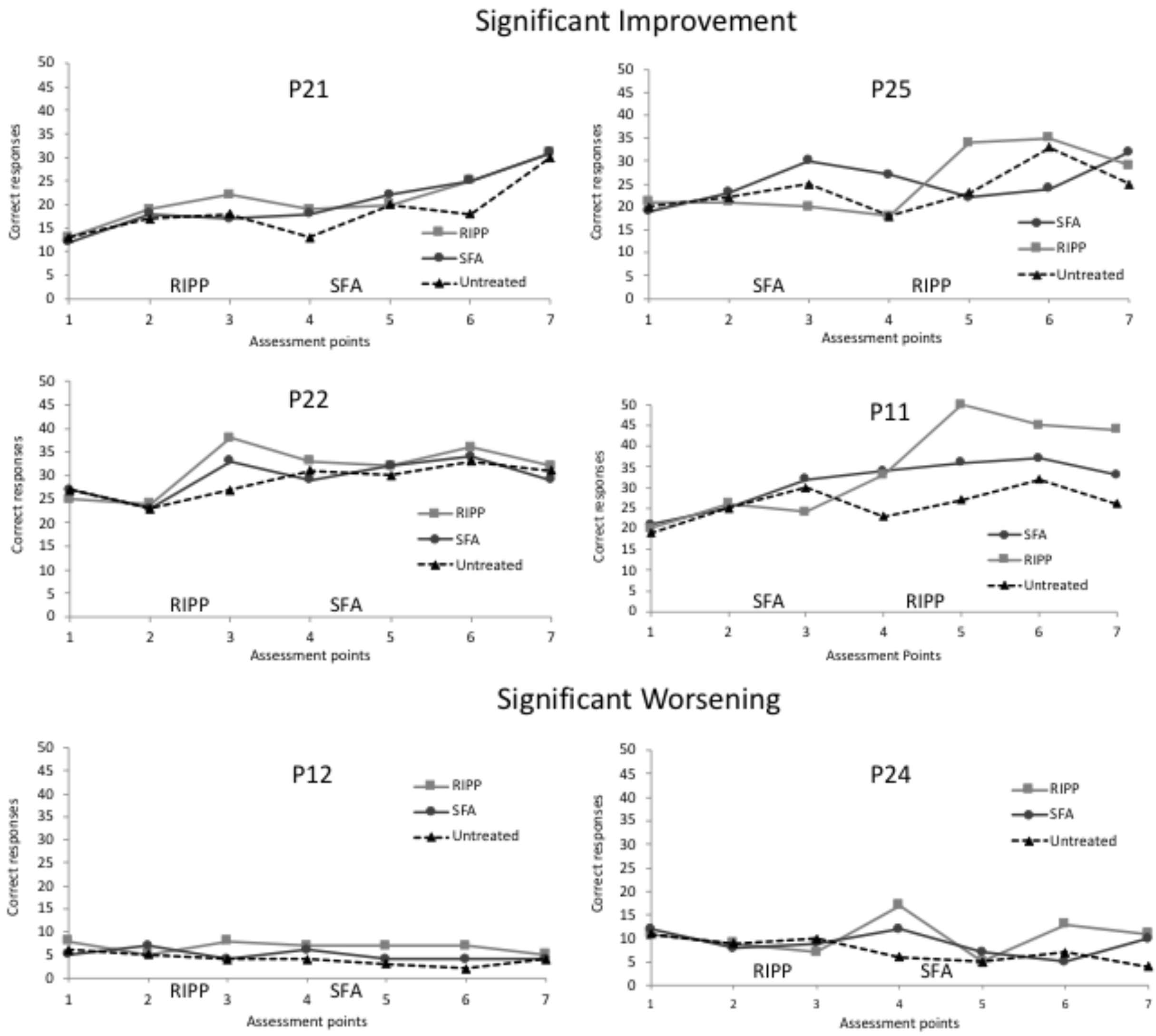

Figure 2. *Accuracy in the three different conditions for each individual who showed a significant change in accuracy in the untreated items (Total number of items in each set =50). RIPP = repetition in the presence of a picture, SFA = Semantic Feature Analysis.*

Table 5

The WEST-Trend values for both the untreated and treated items and the WEST – Rate of Change across all treated items and the two types of treatment separately (SFA & RIPP) for each of the six individuals who showed a significant change in the untreated items.

Participant	Untreated items WEST-Trend		Treated items WEST-Trend		Both Phases: Greater change during therapy (WEST-ROC)		Greater change during SFA therapy (WEST-ROC)		Greater change during RIPP therapy (WEST-ROC)	
	t(49)	p 2-tailed	t(99)	p 2-tailed	t(49)	p 2-tailed	t(49)	p 2-tailed	t(49)	p 2-tailed
Significant Improvement										
P21	3.63	**.001**	6.73	**<.000**	-1.49	.139	.22	. 826	-.42	. 677
P25	3.03	**.004**	4.52	**<.001**	.91	.363	1.6	.115	4.66	**<.000**
P22	2.31	**.025**	2.91	**.004**	3.39	**.001**	.31	**.** 759	4.15	**<.000**
P11	2.11	**.04**	8.92	**<.000**	3.74	**<.000**	2.38	**.021**	3.29	**.002**
Significant Worsening										
P12	-2.1	**.041**	-1.06	.29	.19	.851	-.61	. 547	1.13	.265
P24	- 2.39	**.021**	-.42	.675	-2.68	**.009**	-1.24	.222	-.15	.882

Discussion

There was a significant correlation between the changes in accuracy for untreated items and the change in accuracy in response to the Semantic Feature Analysis treatment, but only a near significant correlation for Repetition in the Presence of a Picture, or both treatment phases combined. However, further investigation found that these correlations were not significantly different, and Bayesian statistics indicated that the data was inconclusive regarding whether there was a relationship or not. Therefore, we cannot rule out that attempted naming and treatment improvements share the same mechanism, however, the weak relationships suggest that there are other contributing factors affecting the extent to which attempting to name brings about improvements.

Looking just at the individuals who showed significant (positive or negative) effects on naming untreated items, there is a strong although not universal relationship. Three out of four of the individuals who showed significant improvements in the untreated items as a result of repeated naming attempts also improved on the treated items in response to treatment. The one remaining participant also improved naming of treated items, however, this was not related to periods of treatment. This suggests that, for this individual, improvement on both treated and untreated items was due to repeated attempts at naming. The stronger positive trend for treated compared to untreated items could be due to the increased exposure to these items during treatment. This highlights the importance of careful interpretation of possible generalisation results, as if control items were presented multiple times, it may be the repetition rather than the treatment which causes the improvements. Consequently, it reinforces the need for ‘exposure’ controls (Nickels, 2002b; Nickels, Best and Howard, 2015) in treatment studies.

Both individuals who showed significantly worsening performance on the untreated items, also did not show treatment-related improvement on the treated items. One participant, even also showed a negative trend for the treated items, suggesting a general decline (perhaps in overall cognitive functioning and/or health) which may not be specifically related to the study.

Finally, as suggested by the equivocal correlations, it was not that case that individuals who improved with treatment necessarily showed attempted naming improvements.

Analysis 3: Factors which predict response to repeated attempted naming

Individual impairment characteristics

Given that only some individuals benefit from repeated attempts at naming, it is possible that improvement is dependent on some key cognitive capabilities remaining relatively intact. In this analysis, we examine possible relationships between repeated naming and performance on a wide range of language and other cognitive assessments

Method

Pearson's correlation was used to examine the relationship between each participant's average attempted naming trend and the following language and wider cognitive skills.

1. Aphasia severity assessed using the Aphasia Quotient from the Western Aphasia Battery – Revised (Kertesz, 2006).
2. Severity of naming impairment using performance on the Nickels' Naming Test (Nickels & Howard, 1994)
3. Extent of phonological and/or semantic impairments, indexed by converting relevant results into z-scores. The z-score for the degree of semantic impairment was calculated from participants' scores on Pyramids and Palm Trees (Howard & Patterson, 1992), PALPA Spoken Word Picture Matching, PALPA Written Word Picture Matching (Kay et al., 1992), and the CAT Semantic Memory test (Swinburn et al., 2004). The z-score for the degree of phonological impairment was calculated from their scores for repetition and reading of both words and non-

words. The z-scores were calculated by converting each participant's score on each test to a z-score (relative to the group mean and standard deviation), then averaging these z-scores across the semantic or phonological tasks. See appendix B for the individual test results.

4. Recognition memory examined using performance on the CAT recognition memory subtest (Swinburn et al., 2004)
5. Executive function as measured by the Modified Wisconsin Card Sorting Test (Schretlen, 2010).

Individual scores on these tasks can be found in Table 6.

Results

No significant correlations were found between the trend in accuracy with repeated attempted naming and overall aphasia severity (r (23) = .191, p = .383), naming severity (r (23) = .263, p = .226), degree of semantic (r (23) = .007, p = .975) and phonological impairment (r (23) = -.330, p = .124) or recognition memory (r (23) = -.029, p = .894). The only significant correlation found was with the Modified - Wisconsin Card Sorting Task (r (22) = .604, p = .003)[2], which is thought to be associated with executive function skills. See Appendix C for the full correlation matrix.

Given the likely complexity of the factors influencing performance across the group, we also examined the patterns of performance shown by the individuals who showed significant trends: the four individuals who showed improved performance from repeated naming, and the two individuals who showed reduced performance.

There were several tasks in which there seemed to be a consistent pattern: Those with significant improvement with repeated naming of the untreated items showed less severe

[2] Note that for the M-WCST, three participants could not complete (P13, P15 & P24). They were assigned a low score of 70. P1 required a lot of direction from the experimenter, and therefore was removed from this analysis. If all four of these participants are removed, the correlation is still significant (r (19) = .475, p = .020).

aphasia overall (higher WAB-AQ), better naming, and relatively less phonological impairment compared to those whom did not improve (see Table 6). There was no systematic relationship between the repeated naming pattern and semantic impairment or the modified Wisconsin Card Sorting Test (M-WCST). This is particularly interesting given the significant correlation between M-WCST and the repeated naming trend across the whole group.

Of the four who showed significant improvement in attempted naming, three had high M-WCST scores, whereas the fourth individual (P21) had an average score. Looking at the two individuals who showed a significant decline in naming untreated items, one performed at an average level, and one could not complete the task (P24).

Table 6

Participants' accuracy measures and scores on various language assessments.

Participant	Repeated Naming Trend	WAB-R (AQ)	Nickels' Naming % correct	Semantic z-score	Phonological z-score	CAT recognition memory	M-WCST	Ave. accuracy at Assessment 1	Ave. accuracy at Assessment 2	Variability Measure (50 items)
P21*	1.10	50.3	37	-2.12	-.09	7	90	.26	.34	20
P25*	.70	89.8	60	0.73	1.58	8	114	.40	.44	10
P22*	.70	81.9	28	.08	.83	9	132	.54	.46	14
P11*	.64	74.6	52	.39	-.09	10	135	.38	.50	14
P4	.48	62.6	68	.64	-.85	10	99	.40	.24	16
P3	.42	84.3	58	.84	-.29	10	99	.54	.40	15
P23	.36	8.4	63	.84	.265	10	90	.38	.50	16
P7	.30	36.5	28	-.23	-.33	5	83	.32	.28	14
P2	.28	7.2	18	.53	-.41	9	101	.16	.06	7
P18	.26	82.9	50	-.60	.42	10	102	.46	.52	13
P6	.08	23	8	.12	-.42	10	83	.02	.06	4
P5	.04	65.7	58	.55	.22	10	107	.46	.42	10
P10	-.12	76.2	58	-.04	.10	10	79	.44	.48	14
P20	-.14	76	43	-.11	1.07	10	91	.44	.44	12
P14	-.16	59.75	35	-.065	.17	10	98	.44	.40	12
P13	-.26	28.4	15	-.42	-1.18	9	(70)	.14	.12	5
P8	-.26	53	32	.13	-.22	10	78	.26	.26	10
P12**	-.26	44	18	.54	-1.73	10	98	.12	.10	5
P1	-.30	65.6	27	-.05	-.83	9	(99)	.16	.18	9
P19	-.54	73.2	38	-.86	.35	10	87	.54	.52	13
P24**	-.60	31.3	15	-1.70	-1.04	8	(70)	.22	.18	12
P15	-.94	76	48	.65	1.07	10	(70)	.50	.38	20
P17	-1.10	69	39	.17	1.42	10	90	.32	.46	21

Note: Participants P13, P24 and P15 were unable to complete the M-WCST so were assigned a score of 70. P1 required help to achieve their score of 99. Variability Measure indicates the amount of variability in accuracy of items across the first two sessions. If accuracy of an item was the same (either both correct or both incorrect, a score of 0 was given, if performance varied, a score of 1 was given for that item. Note: * indicates significant increase in accuracy, **indicates significant decrease in accuracy across the test sessions.

Discussion

This analysis found no relationship between language impairment characteristics and the effects of repeated attempted naming. Morris et al. (2014) also found no correlation between individual impairment characteristics and responsiveness to treatment in this group. However, the individuals' M-WCST score, a task that has been suggested to measure executive function (involving rule discovery and rule following, rule switching, working memory and inhibition), was significantly correlated with the improvement across the untreated items. Moreover, those individuals who showed significant improvement all had M-WCST performance at or above the average. However, while one of the participants who showed significant decline could not perform this task, the other performed within the normal range. While this finding must be treated with caution, it is possible that intact executive functioning of the kind tested by the M-WCST, may be important in order for benefits to occur from repeated naming attempts. For example, cognitive control may be required to monitor responses as either correct or incorrect. For individuals with poor cognitive control, the error responses may have had the same priming as the correct responses, resulting in decreased rather than increased accuracy (e.g., Lambon Ralph & Fillingham, 2007). However, given that P12 performed within the normal range on this task, while cognitive control (as measured by M-WCST) may be necessary to show improvements from repeated attempts at naming, it cannot be sufficient and there must be additional factors influencing benefit. Furthermore, given that the M-WCST involves a variety of executive functioning skills (e.g., rule discovery, monitoring, inhibition, memory), there are various reasons why an individual may perform poorly on the task.

B: Variability in naming accuracy

One of Nickels' (2002a) hypotheses was that improvements as a result of repeated attempts at naming may have been underpinned by item level variability. In other words, for repeated naming to improve performance, a subject would have to display variability in performance at the item level; that is, words they sometimes get right and sometimes get wrong, would be most likely to show performance improvements through repeated naming attempts without treatment (Nickels, 2002a). However, we suggested above that executive function may play a role in determining whether any change occurs. It is therefore possible, that while variability may influence change, it is only when there is both variability and intact executive function that *positive* change occurs. Hence, it is also of interest to examine if variability influences whether there is any absolute change in accuracy (either positively or negatively).

Method

To obtain measure of variability, each item for each individual was scored a 1 if they showed a variable performance in the first two tests, prior to any treatment; and 0 if they showed no variation (either both incorrect or both correct). These variability codes were then summed for each individual to represent the amount of variation across the first two assessments. This value was then correlated with the overall trend for the untreated items and the absolute change (regardless of direction) (see Table 6).

Results

The amount of variation across the first two assessments did not significantly correlate with the amount of improvement in the untreated items ($r(23) = .00$, $p = 1.00$). However, if we look at absolute trend, ignoring direction of trend, then there is a significant correlation between variability and change in accuracy ($r(23) = .71$, $p < .001$).

Discussion

The amount of variability in naming accuracy over the first two assessment sessions was a predictor of absolute change in accuracy from repeated attempts at naming. However, variability was not a predictor of the direction of change. This suggests that a more nuanced version of Nickels' (2002a) hypothesis may be appropriate, where variability in word retrieval accuracy is required for change in performance as a result of attempted retrieval. However, this change may be either positive or negative. We return to what may influence the direction of change in the General Discussion.

General Discussion

This study investigated whether simply attempting to name items repeatedly, once every six weeks, without any treatment or feedback, could lead to improvements in accuracy in people with aphasia. It also aimed to determine which factors might influence such improvements, examining the impact of language and wider cognitive skill, and variability of performance. We examined this using data from 23 people with aphasia who were participating in a treatment study, by examining performance on untreated items. Four individuals showed significantly improved performance with repeated attempted naming, that could not be attributed to the effects of treatment. Given the wide spacing of naming attempts, this is an important finding: For some people with aphasia, even relatively infrequent attempts to name an item can improve word retrieval.

Unexpectedly, four individuals showed a decrease in performance across the seven assessments. For two of these individuals, this unexpected decrease in performance was potentially related to treatment: their accuracy decreased more over phases when there had been treatment of other items. Perhaps for these individuals, there was interference from the treated items and difficulty inhibiting these competing responses.

Improvement from treatment and repeated attempts at naming were hypothesised to share the same mechanism: priming. Each attempt at naming is proposed to strengthen the connections between the semantic and phonological nodes of an item, thereby increasing the chances of successful retrieval the next time (Nickels, 2002a). However, while the two types of treatment showed strong correlations, there was no strong evidence for a relationship (or lack of a relationship) between the degree of change in untreated items as a result of attempted naming, and the change as a result of treatment. We explored this further by examining the six individuals who showed significant attempted naming effects.

Critically, as predicted by a shared mechanism, the two individuals who showed a significant decline in performance simply from the repeated attempts at naming untreated items, did not show treatment-related improvement. Of those who showed significant improvement from attempted naming, all but one also showed the predicted significant treatment-related improvement. The participant who did not show treatment-related improvement, did show improved naming of treated items over the course of the study, but this could be attributed to the result of repeated attempts at naming. Perhaps for him, there was little additional benefit to be gained from being provided the targets during the treatment tasks. Consequently, although we did not find evidence for a correlation between treatment effects and attempted naming effects, the pattern of results remains consistent with the same mechanism underpinning both treatment effects and repeated attempts at naming. However, it also strongly suggests that, unsurprisingly, there are more factors at play which mask any simple relationship.

We next examined participants language and other cognitive skills to see if any factor predicted who would show increased or decreased performance as a result of repeated attempts at naming. Priming has been suggested to increase the accessibility of the phonological form. It has been suggested that those individuals who benefit most from treatment for word retrieval are those who have relatively less of a semantic and phonological impairment (Best, Herbert, Hickin, Osborne & Howard, 2002; Howard et al., 2006). However, we found no correlation between individuals' language skills and repeated naming trend. Nevertheless, consistent with the previous literature those who showed significant improvement did have less severe aphasia, better naming, and relatively less of a phonological impairment, compared to those who showed worsening of performance.

Some authors have suggested that cognitive control plays an important role in monitoring responses: knowing whether an answer is correct or not so that only correct responses are primed and connections strengthened between semantic information and the phonological form (Lambon Ralph & Fillingham, 2007). These authors found that the WCST was correlated with treatment effects (improved naming) across multiple studies (Fillingham et al., 2005a, 2005b, 2006). Indeed, we found a significant relationship between a measure of executive function (Modified Wisconsin Card Sorting Test) and change in performance as a result of repeated attempted naming. Lambon Ralph and Fillingham (2007) suggest that individuals can use a Hebbian learning process to update internal representations of items. If they know that they incorrectly named an item, they can turn the learning system on and adjust their representation, but this will not happen for incorrect responses. For this to work correctly, participants must be able to monitor correct and incorrect responses. This is argued to require some executive functioning skills such as: monitoring, memory and attention. While appealing, and apparently consistent with executive skills predicting treatment outcomes in their studies (e.g., Fillingham et al., 2005a; 2005b; 2006), this account is not consistent with the fact that Lambon Ralph, Fillingham and colleagues did not find the predicted difference between errorless and errorful treatment conditions. Similarly, there was no significant correlation between executive function and treatment-related improvement in an analysis of the treatment data from the participants reported here (Morris et al., 2014). Therefore, this association must be treated cautiously, particularly given only a single measure of executive function was used here.

It is possible nonetheless that executive skills could be important for self-directed learning, even if not for treatment-related improvement. Our results lent some evidence to this hypothesis but do not support this being the only critical factor in improvement as a result of repeated attempted naming: P12, who showed a significant decline in performance, performed in the normal range on the Wisconsin task. Clearly, therefore, not everyone who has intact executive function skills (as measured by the Modified Wisconsin Card Sorting Test) will show improvements in repeated attempted naming - additional cognitive factors or skills are required. Further research is required to replicate this correlation between executive functioning skills and repeated attempted naming. It would be particularly important to use a wider range of cognitive tasks to attempt to isolate different aspects of cognitive control such as attention, working memory, monitoring and inhibition.

Nickels (2002a) hypothesised that variability in accuracy may be a prerequisite in order to benefit from repeated attempts at naming - without variability, there would be no change in performance. In contrast, if items are sometimes correct and sometimes incorrect, over time, more items can be correctly retrieved and primed. Our findings supported this hypothesis, variability on the first two naming attempts, was found to be significantly correlated to change in accuracy of the untreated items. However, variability was not an indicator of direction of change. This suggests that while variability was important for change in accuracy, in order to produce positive change, perhaps by only reinforcing the correct items, another factor was at play. It seems plausible that perhaps it is both variability and some aspect of executive functions that help drive improvements from repeated attempts at naming.

To summarise, this study supports the hypothesis that repeatedly attempting to name an item can lead to improved accuracy for at least some individuals with aphasia, replicating Nickels (2002a) finding. Critically, while Nickels' study reported this 'attempted naming' effect following daily practice, here we find the effect with six week intervals between naming attempts.

This finding indicates that feedback and/or treatment may not always be necessary to influence word retrieval. Perhaps, for some people with aphasia providing opportunities to retrieve words through, for example, social interaction could result in additional recovery. However, the finding that some individuals get worse with repeated attempts without feedback, also needs careful consideration.

Importantly, not everyone who responds to treatment, improves through repeated naming attempts, nor does everyone who improves through attempting naming gain additional benefit from treatment. Nevertheless, we argue that it may be the same priming mechanism which underpins both types of improvement. Moreover, we hypothesise that both item-level variability in accuracy across items and executive cognitive skills may have an impact on whether an individual will benefit from repeated naming attempts. Consequently, it seems important to improve our understanding of the role of non-linguistic cognition, and executive function in particular, including the ability to monitor one's own performance and prevent learning from erroneous responses. This is particularly pertinent given the conflicting evidence regarding the role of these abilities in treatment.

Finally, only a small proportion of participants showed this effect. We suggest that this could be because of the large spacing between naming attempts (six weeks). While priming effects are argued to be long lasting in unimpaired participants, very little is known about the time course of repetition priming in people with aphasia. This study provides a reason to investigate this further.

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Appendix A

Coefficients used to multiply item accuracy (0 or 1) for WEST-ROC and WEST-Trend statistics

	Weighted Score at each Assessment Number						
	1	2	3	4	5	6	7
WEST-ROC: Greater during therapy Phase 1	-5	-10	13	8	3	-2	-7
WEST-ROC: Greater during therapy Phase 2	6.71	0	-6.71	-13.42	11.18	4.47	-2.24
WEST-ROC: Greater during therapy (both phases)	1	-10	7	-4	13	2	-9
WEST-Trend: Trend across all study phases	-3	-2	-1	0	1	2	3

Appendix B

Participants' scores on the eight language tasks which created the semantic and phonological z-scores.

	Semantic Z-Score calculated from:				Phonological Z-Score calculated from:			
Ppt	Pyramids & Palm Trees Test	PALPA Spoken Word Picture Match	PALPA Written Word Picture Match	CAT – semantic memory	Repetition (words)	Repetition (non-words)	Reading (words)	Reading (non-words)
P21*	42	31	30	7	35	5	41	3
P25*	51	40	37	10	58	12	59	10
P22*	45	39	37	10	59	12	36	4
P11*	50	36	40	10	41	3	49	2
P4	51	39	37	10	36	1	22	0
P3	51	40	40	10	25	3	38	5
P23	51	40	40	10	44	7	45	3
P7	47	37	37	9	54	3	27	0
P2	49	39	39	10	42	7	10	1
P18	42	38	37	9	60	9	37	1
P6	44	40	38	10	47	5	19	0
P5	50	39	37	10	43	3	53	5
P10	46	37	36	10	55	6	25	3
P20	49	39	39	8	60	7	56	8
P14	47	38	39	9	58	7	37	0
P13	46	34	33	10	26	1	3	0
P8	48	36	38	10	58	6	15	0
P12*	49	40	37	10	2	0	2	0
P1	49	35	33	10	37	2	17	0
P19	46	31	37	9	52	9	47	0
P24*	46	34	7	9	27	3	9	0
P15	49	40	40	10	58	9	54	7
P17	48	36	39	10	57	10	59	10

Appendix C

Correlation results

Note: To correct for multiple comparisons, p-value must be below .007 to be considered significant. Significant results p < .007 are indicated with an asterisk

		Repeated Attempted Naming	WAB	Nickels Naming	Semantic Z-Score	Phonological Z-Score	CAT Recognition Memory
WAB	Pearson's r	.191					
Nickels Naming	Pearson's r	.273	.729*				
Semantic Z-Score	Pearson's r	.007	.420	.393			
Phon Z-Score	Pearson's r	-.029	.662*	.461	.167		
CAT Recog Memory	Pearson's r	-.330	.355	.276	.444	.105	
M-WCST	Pearson's r	.589*	.526	.290	.325	.249	.101

Chapter 3 (Paper 2)

An Investigation of the Time Course of Repetition Priming of Word Retrieval

Abstract

In picture naming, repetition priming refers to the phenomenon that the second time a picture is named response latencies are faster. This has been well established in the short term and has also been found at long delays (up to 48 weeks). However, studies examining lags of greater than two days have all used identical pictures, making it impossible to distinguish priming of word production and visual priming.

This paper presents the first experiments exploring the time course of repetition priming of picture naming in young adults, while minimising visual priming by using different target exemplar pictures at each presentation: Experiment 1 examined lags of minutes, one day and one week, while Experiment 2 examined lags of one, two and four weeks. Following their first re-presentation targets were repeated in any subsequent session(s) to examine whether extra naming attempts produced additional priming.

Both experiments showed significant priming of naming latency at all lags. In Experiment 1, the magnitude of priming was significantly less at the longest delay of one week. In Experiment 2, the magnitude of priming remained stable across the four weeks. Neither experiment showed any significant effects of additional presentations.

These experiments are the first to demonstrate that there are long lasting changes in the efficiency of word production processes that are independent of visual priming. Compared to previous studies using identical pictures at similar delay intervals, we found reduced levels of priming suggesting that the previously reported long-term priming effects were inflated by visual priming.

Introduction

Repetition priming refers to the finding that an individual's ability to produce or identify an item is improved if they have already experienced that item in the context of the same or a related task (for review, see Schacter & Buckner, 1998). In the context of word retrieval, a single repeat presentation of a picture for naming has been shown to significantly reduce response latencies for speakers to name that picture over both short and longer lags (e.g., Cave, 1997; Mitchell & Brown, 1988). This is the focus of the research presented here.

There is a clear consensus that if individuals are re-presented with an identical picture for naming within the same session, they are significantly faster to name it (e.g., Durso & Johnson, 1979; Gollan, Montoya, Fennema-Notestine and Morris, 2005; Wheeldon & Monsell, 1992). For example, Durso and Johnson (1979) examined the time course of priming within a session, by increasing the number of intervening items between the first (prime) and the second presentation of the target. They found participants were on average 200ms faster to name primed targets with no intervening items, as compared to unprimed targets. When they increased the number of intervening stimuli before the repetition to 25 and then to 50, participants were 165ms and 159ms faster, respectively, for primed targets compared to unprimed items, suggesting decay of the magnitude of priming with the lag between prime and target.

Repetition priming of word retrieval has also been demonstrated over much longer periods. For example, Mitchell and Brown (1988) found significant priming across one to six weeks with the magnitude of priming remaining stable. Compared to unprimed controls, primed targets displayed a reduction of response latency (priming) of 70ms with one week and 83ms with six weeks from initial presentation. Cave (1997) extended these time delays even further and found reductions in response latency of approximately 70ms at six weeks, 50ms at 16 weeks and 25ms at 48 weeks. Hence, having named the item just once before, participants were faster to name it for the second time, even up to 48 weeks later, compared to new, unprimed, control items.

One mechanism proposed for this priming of response latencies, relies on episodic memory, the trace memory of having seen that picture before and remembering the correct response produced. However, it has been argued that this cannot explain longer term priming effects in particular: Mitchell and Brown (1988) found that after six weeks, individuals were unable to correctly identify whether they had seen the picture before, despite displaying priming, indicating that priming and explicit memory of the event are dissociable. Cave and Squire (1992) found priming effects with individuals with amnesia that, despite the significant amnesic memory impairment, were similar to those of unimpaired participants, once again making episodic memory an unlikely explanation for priming of word retrieval.

Other authors have interpreted these priming results as evidence of language facilitation: Having already selected, retrieved, and produced the most appropriate word to represent the picture once, this linguistic process is more efficiently performed the second time (e.g., Cave & Squire, 1992; Mitchell & Brown, 1988; Wheeldon & Monsell, 1992). However, visual processing is also involved in picture naming and efficiencies in visual processing of the image may also reduce naming latencies, and therefore be another possible mechanism for priming. Cave and Squire (1992) manipulated some aspects of the pictures presented to see if visual priming contributed to priming. Pictures that were changed in size, shading or token (different exemplar), had a smaller priming effect two days later compared to identical items, but were still named faster on average than at the first presentation and compared to new control items. The 20 pictures that were changed in token were named on average 81ms faster than unprimed control items, compared to 128ms faster for identical pictures. These studies indicate that priming of lexical retrieval does occur and that it lasts up to two days (Cave & Squire, 1992).

Wheeldon and Monsell (1992) also addressed the issue of visual priming by using naming in response to a definition of the target word as a prime rather than naming of the identical picture to the target. This produced priming of subsequent picture naming of 120ms after 2-7 intervening items (10-35 seconds) and 77ms after 60-120 intervening items (6-12 minutes). This result rules out visual priming as the only mechanism driving priming of picture naming. However, it still remains to be seen whether lexical priming (in the absence of visual priming) occurs at longer-term intervals. Indeed, it seems implausible that saying a word just once would have an effect 48weeks later (Cave, 1997). Surely, these (common) words would have been produced many times over the intervening weeks along with thousands of other lexical items and this would wipe out any effects from the initial priming event. Hence, one aim of the current study was to evaluate whether using primes which are different exemplars of target words results in priming of lexical retrieval at longer intervals than has been evaluated to date.

Another dimension of repetition priming is the cumulative effect of multiple repetitions on the strength and durability of priming. This has not been widely examined for unimpaired speakers, but it appears that, at least within a session, there is little or no benefit. Brown, Jones and Mitchell (1996), found that when items were presented four times in the same session (separated by approximately 80 items), the largest reduction in response times occurred between the first and second presentation (125ms). There was small, but significant, additional priming of 31ms on the third presentation, but not the fourth (1ms). The authors argue that this suggests that there is some incremental benefit of prime repetition with a ceiling effect blocking improvement beyond the third presentation. Both Wingfield, Brownell and Hoyte (2006), and Gollan et al. (2005), included five presentations of target words in a picture naming task in a single session and found smaller but incremental reduction in response time with each repetition. In a longer term priming study over one month, Wiggs, Weisberg and Martin (2006) examined the magnitude of priming for identical pictures named either once or three times in the first session. They found that participants displayed significantly larger priming effects following three repetitions than one repetition at delays of: minutes (within session), one day, and one week later, but not one month. By one month, any additional priming as a result of three presentations had decayed to the same level as one presentation. However, it is possible that longer intervals between repetitions (as opposed to within a single session), may produce a larger benefit from repeated practice, helping to sustain repetition priming over time. This has been found within the learning literature, where spaced learning has been shown to be more beneficial than massed (e.g., Jackson, Maruff & Snyder 2013; Sage, Snell & Lambon Ralph, 2011; Sobel, Cepeda & Kapler, 2011).

Whether additional repetitions are beneficial, and whether priming is found longer term with different exemplars of the target can help shed further light on the exact mechanism(s) of repetition priming. Previous studies have clearly shown that visual identification is not the only process primed in the short term (e.g., Wheeldon & Monsell, 1992) and that episodic memory is dissociable from repetition priming in the longer term (e.g., Cave & Squire, 1992). However, the question of whether longer term priming is underpinned by priming of word retrieval rather than visual processing remains unanswered.

The current study builds on the previous literature by being the first to explore priming of word retrieval over several days (Experiment 1) and weeks (Experiment 2) while minimising any impact of visual processing by using different (visual) exemplars of items. This enables further investigation of whether longer-term priming effects are visual and/or language based. In addition, both Experiment 1 and 2 also are the first to examine whether additional repetitions of the target increases the size and robustness of the priming effect beyond a single session. Our aim is to clearly specify the time course of repetition priming in order to better understand the locus of priming and facilitation of the lexical process.

Experiment 1

Method

Participants. Participants were 24 (20 female, 4 male) university students recruited through Newcastle University and aged between 18 and 28 years (mean: 22.2; SD: 3.2). Participants were all young adult native speakers of British English with normal or corrected to normal vision and hearing. They reported no learning difficulties or neurological impairment. Fifty-five percent of participants were undergraduate students, with the remainder being postgraduate students. All participants were given £20 at the end of the final session for their participation. See Appendix A for additional demographic information.

Materials. Stimuli were coloured photographs depicting single objects on a plain white background. The photographs were selected from various sources: Hemera Photo Object Library (Hemera Technologies Inc, 1997-2000), our own picture library or from other open access sources. All images were approximately the same size (maximum 500 x 500 pixels). Target items comprised of 192 items each of which had four different exemplar pictures with a total of 768 target pictures (see Appendix C for a list of the target stimuli). This allowed targets to be presented up to four times in one condition (see Figure 2). The pictures all had name agreement of 90% or higher from a prior norming phase with different participants from the same population. Each picture had been named in a previous name agreement study by an average of 19 individuals (range: 16-22), and a correct response was scored for only the exact target name.

The target items were divided into six sets of 32 items matched on name agreement, spoken word (log) frequency (van Heuven, Mandera, Keuleers & Brysbaert, 2014), length in syllables (Davis, 2005), age of acquisition (Kuperman, Stadthagen-Gonzalez & Brysbaert, 2012), concreteness (Brysbaert, Warriner, & Kuperman, 2014) and visual complexity (as indicated by file size, Székely, & Bates, 2000). These sets were then assigned to conditions, counterbalancing such that every set appeared in every condition an equal number of times and that exemplars appeared in a different order in different versions. This counterbalancing resulted in 24 versions of the experiment, and consequently we recruited 24 participants so that each participant completed a different version.

An additional 114 pictures were selected to act as fillers. These pictures were of 92 items with 70 items having 1 exemplar; 16 items with 2 exemplars and 3 items with 4 exemplars.

Procedure

Participants were tested individually at Newcastle University. All sessions were run using the experimental software DMDX (Forster & Forster, 2003). The experiment began with written instructions displayed on the screen explaining that participants would see pictures of single items, which they were asked to name aloud with one word as quickly as possible. They were informed that some items might appear multiple times so not to hesitate to say a name again. These instructions were also paraphrased verbally by the experimenter. Each trial began with a fixation cross displayed for 250ms, followed by the picture, which remained until the participant made their response and the trial was manually terminated by the experimenter, or for a maximum of 5000ms. A blank screen then appeared for 500ms before automatically moving on to the next trial (see Figure 1). Each session consisted of 165 items and lasted approximately 10 minutes.

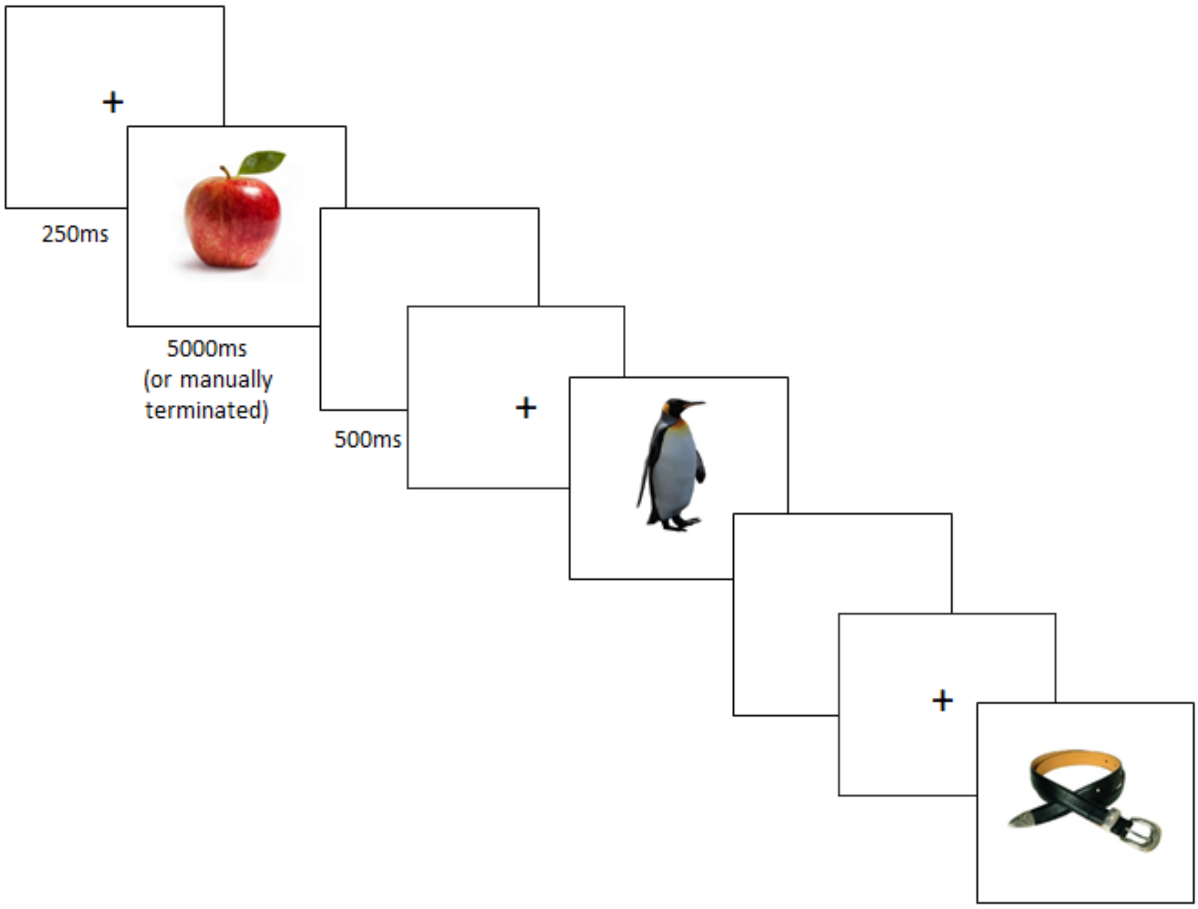

Figure 1. An example of the experimental sequence for Experiment 1.

Participants were tested in three sessions on separate days: Session 1 (on Day 1), Session 2 (on Day 2) and Session 3 (on Day 8). This allowed manipulation of 3 lags for repetition priming (see Figure 2): a lag of several minutes within Session 1 (Minutes), a lag of one day in Session 2 (Day), and a lag of one week in Session 3 (Week). In each session, there was also a set of new unseen control items in order to control for any effects of session by providing baseline naming latency for that session. In addition, the effect of number of repetitions on priming was examined by repeating items in more than one session. On Day 1, sets assigned to all three target delay conditions were presented for the first time (Minutes, Day, Week) as well as the control set 'Control Session 1'. The Minutes items were presented for the second time within the session, separated by approximately 50 items and three minutes from the first presentation (whilst ensuring that target items did not appear in the same consecutive order: Mean lag = 52 items; range 51-54). On Day 2, the items in the Day priming condition were presented for the second time, items in the Minutes priming condition were presented for the third time, and Control Session 2 items for the first (and only) time. In the third session on Day 8, the Week items were presented for the second time, the Day items for the third time, the Minutes delay items were presented for the fourth time, and Control Session 3 items for the first time.

Condition	**Session 1** (Day 1)	**Session 2** (Day 2)	**Session 3** (Day 8)	**Repetition Delay**	**Attempts**
Minutes	 Test 1  Test 2	 Test 3	 Test 4	**Minutes,** 1 day, 1 week	4
Day	 Test 1	 Test 2	 Test 3	**1 day,** 1 week	3
Week	 Test 1		Test 2 	**1 week**	2
Control				not repeated	1

Figure 2. A visual representation of the experimental design for Experiment 1.

Response scoring. Responses were scored correct when the item was named with the target word. Close alternative names (e.g., *spectacles* for *glasses*) were scored as correct if the participant also used the same alternative name on any additional presentations (alternative exemplars) of that item. Only participants' first attempt at an answer was scored, with any later self-corrections marked incorrect (e.g., for the target *duck* the response *bird...duck* or *bir...duck* were both scored as incorrect). However, a single phoneme before a full attempt was ignored (e.g., *s...duck* was considered correct), or similarly, if they produced part of the target followed by the full correct response (e.g., *dʌ duck* was scored correct). The response time was always measured from the start of the completed word.

Data analysis. The recordings of responses were opened in CheckVocal (Protopapas, 2007), coded as correct or incorrect, and response latencies adjusted as necessary such that they coincided with when the correct (or alternative) response was initiated (e.g., *s...duck* was measured from the start of *duck*). These data were then analysed in R-Studio (R Core Team, 2013). Only correct responses were included in response time (RT) analyses, removing 193 error trials (2%). Additionally, any responses which were delayed for an external reason (e.g., talking about previous trial, coughing), were excluded, further excluding 11 trials (0.1%). Following inspection of scatterplots of responses separated by condition and participant, any responses over 3000ms were considered to be outliers and therefore were removed from further analysis. This removed 12 data points (0.1%). In order to improve normality of the model residuals, a logarithmic transformation was used.

For all analyses, a linear mixed effect model was constructed in R-Studio using the lme4 package (Bates, Maechler, Bolker & Walker, 2015) to examine the effect of the condition (the delay condition and presentation number, e.g., first presentation of day condition) on response times. The dependent variable was log RT, with the presentation number and time delay as the fixed effect. As random effects, we had intercepts for subjects and items (LogRT ~ Condition + (1 |Subject) + (1 |Item). We also entered by-subject and by-item random slopes for the effect of condition, however, the model failed to converge. The reduced model, with only random intercepts for participants and items was significant (χ^2 = 1768.4, p = <.001). Contrast coding was used to compare response latency for naming of repeated items in each delay condition (Minutes, Day, and Week) to the latency in the first presentation, whilst also controlling for session effects (difference in control items across sessions). The full matrix for the contrasts is presented in Appendix D and described in further detail below. The statistical package Multcomp (Hothorn, Bretz & Westfall, 2008) was then used to run one-way analyses on each comparison of interest. Holm-Bonferroni was used to correct for multiple comparisons. For accuracy data, a logistic mixed effects model was fitted (Accuracy ~ Condition + (1 | Subject) + (1 |Item)) which was significant (χ^2 = 1577.3, p = <.001). The same contrasts were then used for all analyses to compare the conditions of interest. Priming was evaluated by comparing the difference between first and second presentations of items, minus any difference between the two sets of control (unrepeated) stimuli from the same two sessions.

Results

The group mean and standard deviation response times are presented in Table 1 for each condition and presentation separately.

Table 1

Experiment 1: response times and error rates for each condition across the three sessions.

Condition	Session 1 (Day 1)		Session 2 (Day 2)	Session 3 (Day 8)
RT (ms)	Mean (SD)	Mean* (SD)	Mean (SD)	Mean (SD)
Minutes	772.9 (259.7)	694.7 (177.1)	687.4 (181.2)	708.6 (193.1)
Day	773.6 (247.6)		699.8 (174.8)	702.9 (184.9)
Week	763.5 (233.7)			722.5 (192.1)
Controls Session1	776.1 (238.9)			
Controls Session2			767.2 (239.4)	
Controls Session3				763.6 (248.6)
Error Proportion				
Minutes	.031 (.17)	.017 (.13)	.013 (.11)	.023 (.15)
Day	.023 (.15)		.012 (.11)	.012 (.11)
Week	.029 (.17)			.020 (.14)
Controls Session1	.026 (.16)			
Controls Session2			.023 (.15)	
Controls Session3				.022 (.15)

*NOTE: * This column refers to the second presentation of Minutes targets in Session 1.*

Analysis 1: Priming effects and effects of prime-target delay. The primary analysis of interest was whether individuals were faster to name items on the second presentation in each of the delay conditions while taking into account any variation in overall response times between sessions (e.g. due to practice/boredom) by using the control items from each session. Figure 3 shows the latencies for the first and second presentations of each delay (Minutes, Day, Week) along with the control items from the same sessions. There was, on average, 93ms of priming for items repeated within minutes in the same session, 77ms when repeated a day later, and 31ms when repeated a week later. This priming effect was analysed using contrast coding to compare the difference in response latency from first presentation to second presentation, compared to the difference in the relevant controls across sessions. For example, to examine the priming effect over one day, the first presentation of the Day set was coded as -1, and the second presentation was coded as 1 to provide the difference between these two sets (the raw priming effect). The effect of session was controlled by coding Control Session 1 as 1 and Control Session 2 as -1, and all other cells set to zero (see matrix in Appendix A). For the Minutes comparison, the control was for changes across the course of the session and was achieved by splitting Control Session 1 in half (first half and second half) for contrasts. Significant priming was found at all three delays between prime and target presentation (see Table 2).

Whether there was a significant difference in the amount of priming of response latency at different delay conditions was examined by comparing whether the difference from first to second presentation versus the difference between the control conditions was greater for Minutes, Day or Week. For example, to examine if there was any difference between Minutes and Day priming, Minutes 1 was coded as -1, Minutes 2 as 1; with Control Session 1A as 1, Control Session 1B as -1. Day 1 was coded as 1, Day 2 as -1; with Week 1 coded as -1 (to act as session 1 control), and Control Session 2 as 1. As Table 2 shows, there were no significant differences found in the amount of priming between the Minutes and Day conditions (p=.798). However, there were significant differences in the amount of priming in the Week priming condition compared to both Minutes (p=.031) and Day (p=.031) conditions.

There were no significant effects of condition on accuracy nor any differences between the delays. The individual patterns are discussed in Chapter 4 (Creet, Robidoux, Howard, Morris, & Nickels, 2018c).

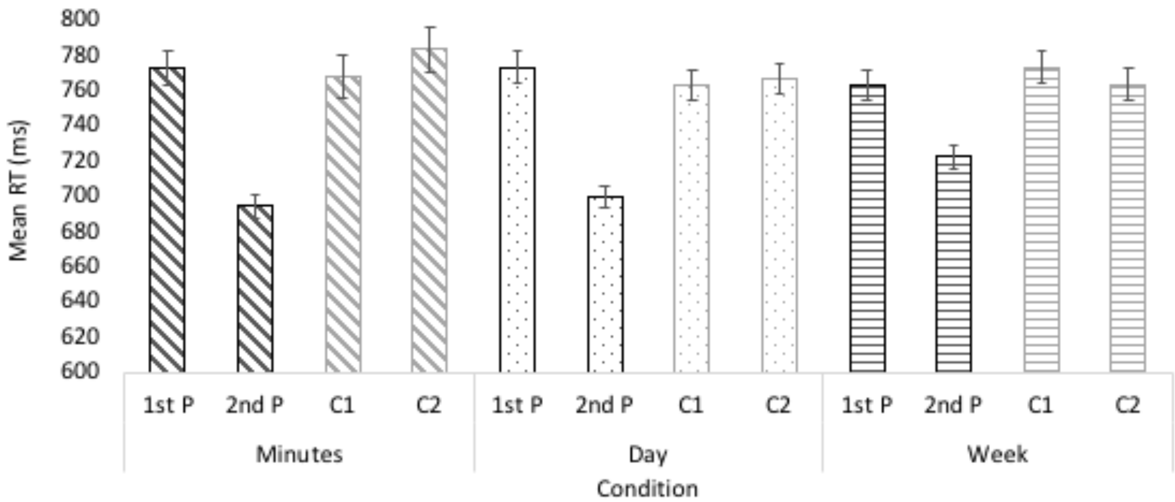

Figure 3. Experiment 1: Mean response times (RT) and standard error bars for the first presentation of items (unprimed), the second presentation of items (primed) compared to the control items from the same two sessions for each delay condition. 1st P = first presentation; 2nd P = second presentation; C1 = controls for first presentation; C2 = controls for second Presentation. Note that first control for Day is the first presentation of Week, and the first control for Week is the first presentation of Day.

Table 2

Experiment 1: Results of Linear Mixed Effects Models examining priming in each delay condition, controlling for session effects, and comparisons of these priming effects (each group of three p-values is adjusted for 3 tests using Holm-Bonferroni corrections)

Contrasts	**Estimate**	**Std. Error**	**z value**	**p value (Holm)**
Response Time Analyses				
Overall Priming Effect:				
Minutes Priming	-.042	.008	-5.278	<.001
Day Priming	-.039	.006	-6.239	<.001
Week Priming	-.016	.006	-2.517	.001
Comparison between delay conditions:				
Minutes vs Day Priming	.003	.010	-.256	.798
Minutes vs Week Priming	-.026	.010	-2.567	.031
Day vs Week Priming	-.022	.009	-2.475	.031
Accuracy Analyses				
Overall Priming Effect:				
Minutes Priming	.979	.642	1.525	.382
Day Priming	.559	.549	1.020	.616
Week Priming	.391	.508	.769	.616
Comparison between delay conditions:				
Minutes vs Day Priming	.420	.845	.496	1
Minutes vs Week Priming	.588	.819	.718	1
Day vs Week Priming	.240	.748	.321	1

Analysis 2: Effects of Cumulative Presentation. We also examined whether there was any additional benefit from repeating items more than once in order to determine whether effects of repetition priming were cumulative and how this varied with lag. Figure 4 shows the average amount of priming in milliseconds for repeated items in Sessions 2 and 3, to compare the number of presentations which have occurred.

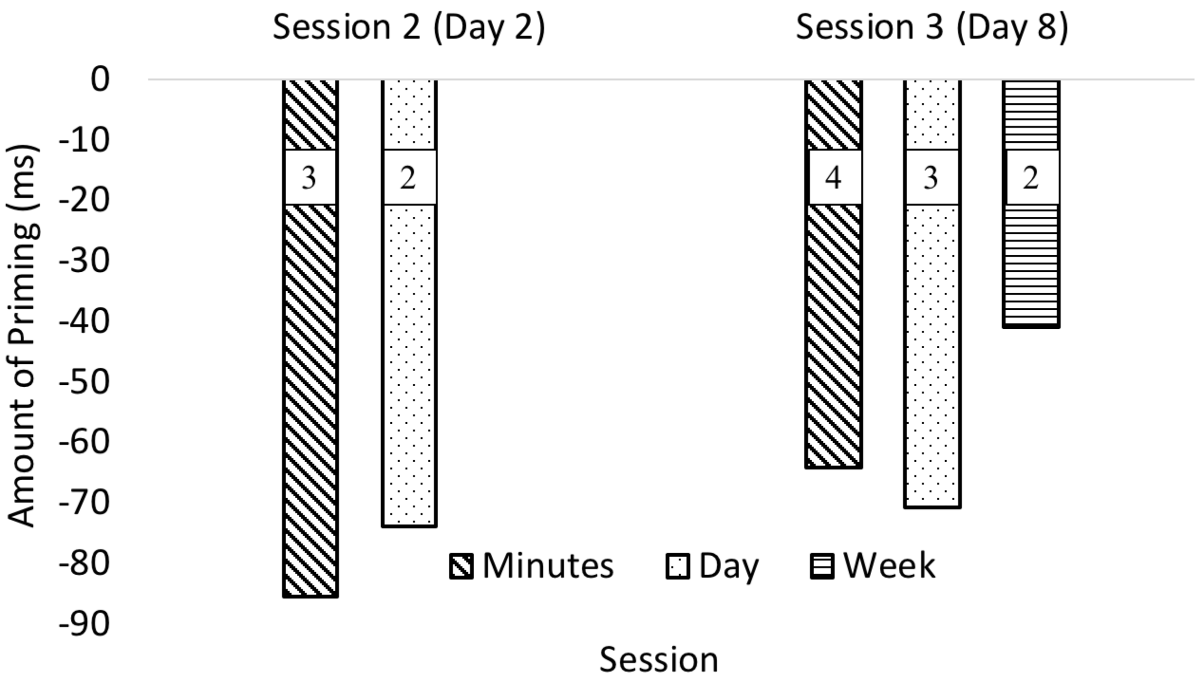

Figure 4. Experiment 1: The amount of priming in milliseconds comparing the first presentation to the repeated presentation in Session 2 and 3. The presentation number is labelled on the bars (e.g. in Session 2, Minutes items are presented for the third naming attempt, and Day items for the second naming attempt).

We examined whether there was any benefit from additional presentations on latencies of primed items, by comparing the difference in the amount of target priming depending on the number of prior naming attempts. For example, in Session 2, Day items were presented for the second time, and this was compared to Minutes items which were presented for the third time (having named these items twice in Session 1). This was achieved by looking at the difference in the response latency compared to the first presentation of these items. As the analysis compares across the same two sessions in both conditions, no control for the effect of session is required (the control items cancel each other out in the contrasts).

As is clear from Table 3, there were no significant effects of number of presentations in any of the within-session comparisons. However, in Session 3 the items that were presented for a third occasion (Day 3) were close to showing significantly more priming than those being presented for a second time (Week 2).

Table 3

Experiment 1: Results from comparisons of additional presentations (each group of four p-values is adjusted for four tests using Holm-Bonferroni corrections)

Contrasts	**Estimate**	**Std. Error**	**z value**	**p value (Holm)**
Response Latency Analyses				
Session 2: Minutes3 vs Day2 Priming	-.008	.006	-1.223	.546
Session 3: Minutes4 vs Day3 Priming	.004	.006	.563	.574
Session 3: Minutes4 vs Week2 Priming	-.008	.006	-1.335	.546
Session 3: Day3 vs Week2 Priming	-.015	.006	-2.357	.074
Error Analyses				
Session 2: Minutes3 vs Day2 Priming	.075	.585	.128	1
Session 3: Minutes4 vs Day3 Priming	-.577	.546	-1.056	1
Session 3: Minutes4 vs Week2 Priming	-.443	.506	-.877	1
Session 3: Day3 vs Week2 Priming	.340	.557	.610	1

Experiment 1 Discussion

This experiment explored the time course of priming across one week and whether young adults showed any additional benefit in naming from multiple (re)presentations of targets. Three different delays of the target following the first presentation were examined: 50 intervening items (approximately three minutes), one day, and one week. We used different exemplars of pictures to minimise any visual benefits from previously identifying the identical picture. Significant priming was shown at all three intervals examined (Analysis 1). However, no significant cumulative priming was found from multiple repetitions of the same item (Analysis 2).

The reductions in response latencies observed in this experiment, using different exemplars of targets at each presentation, were less than have previously been reported when using identical pictures. For example, within session, Durso and Johnson (1979) found priming of 159ms at 50 intervening items, compared to 93ms in the current study. After a delay of two to five days, Cave and Squire (1992) found priming of 124ms, compared to the 77ms we found with a one day lag. Similarly, at a delay of one week, Mitchell and Brown (1988) found a delay of 70ms compared to our 31ms. This supports the view that the effects of repetition priming that are observed using identical pictures, involve some efficiencies in visual processing or identification. That the priming remains significant with different exemplars of items indicates that significant processing gains are also possible in the word retrieval process at longer lags than have previously been demonstrated within sessions (e.g., Durso & Johnson, 1979; Wingfield et al., 2006).

Increasing the interval between target repetitions resulted in reduced priming effects, from an average of 93ms within minutes, to 77ms after a day and 31ms after one week. However, these reductions were only significant when comparing the week delay to the other shorter intervals. This decline over the three sessions contrasts with Cave and Squire's (1992) findings that there was no difference in priming from two to seven days, both days resulting in around 95ms of priming for the control participants. This raises the possibility that visual priming effects are more stable over time than lexical effects.

Since significant decay was found at one week, and the amount of priming was relatively small compared to previous studies using identical exemplars, it was possible that a longer lag between presentations may show no priming with different exemplars. This was explored in Experiment 2.

Experiment 2

This experiment examined the time course of longer term priming from one week to four weeks using different exemplars of targets at each presentation, using similar methodology to above but over longer lags and new participants. Once again, we examined the effects of additional repetitions of items, using up to four presentations (three re-presentations) of a target.

Method

Participants. Participants were 28 young adults (18 females, 10 males) aged 18-30 years (M:22.8yrs, SD:3.7), recruited through Newcastle University. Participants were all native speakers of British English with normal or corrected to normal vision and hearing. They reported no learning difficulties or neurological impairment. Fifty-seven percent were undertaking undergraduate studies with the rest in postgraduate education. All participants were given £20 at the end of the final session for their participation. See Appendix B for additional demographic information on the participants.

Materials. The target pictures used in this experiment were 189 items with the three least accurate items excluded, from the 192 targets used in Experiment 1, with four different exemplars totalling 756 target pictures (see Appendix C). The target items were divided into seven sets of 27 items matched as in Experiment 1. These sets were then randomly assigned to conditions that were counterbalanced such that every set appeared in every condition an equal number of times, with a varied order of exemplars. This counterbalancing resulted in 28 versions of the experiment, therefore, we recruited 28 individuals, with each participant completing a different version. An additional 101 pictures were selected to act as fillers.

Procedure. The same picture naming procedure was used as Experiment 1. Participants named aloud 113 coloured photographs of single items in each of 4 separate sessions over a period of four weeks. Three sets of 27 items were repeated for naming (using different exemplars) at three delays: one week, two weeks, or four weeks (see Figure 5 below). Previously unseen control items were once again presented in each session to enable statistical control for any session effects.

Condition	Session 1 (Day 1)	Session 2 (Day 8)	Session 3 (Day 15)	Session 4 (Day 29)	Repetition Delay	Attempts
1 Week	 Test 1	 Test 2	 Test 3	 Test 4	**1 week**, 2 weeks, 4 weeks	4
2 Weeks	 Test 1		 Test 2	 Test 3	**2 weeks**, 4 weeks	3
4 Weeks	 Test 1			 Test 2	**4 weeks**	2
Control	 Test 1	 Test 1	 Test 1	 Test 1	(not repeated)	1

Figure 5. A visual representation of the experimental design for Experiment 2

Data analysis. The same scoring procedure and data processing was used as in Experiment 1. Likewise, only correct responses were submitted to response time analyses, removing 259 incorrect responses (2.6%), with a further 14 responses removed due an external delay (e.g., laughing or distraction). Again, after visual inspection of scatterplots of response times separated by condition and participant, responses above 3000ms were removed as outliers. This resulted in the removal of 28 responses (0.3%). Response latencies were log transformed to improve normality of the residuals and meet the assumptions of the model. For all analyses, a linear mixed effect model was constructed in R using lme4 package (Bates et al., 2015) to examine the effect of the condition (delay and presentation; 13 conditions) on response times. The same model was constructed as in Experiment 1. The dependent variable was log RT, with the presentation number and time delay as the fixed effect. As random effects, we had intercepts for subjects and items (LogRT ~ Condition + (1 |Subject) + (1 |Item)). By-subject and by-item random slopes for the effect of condition were also entered, however, again, the model failed to converge. The reduced model, with only random intercepts for participants and items was significant ($\chi^2 = 2593.5$, $p < .001$). Contrast coding was used to compare response latency for naming of repeated items in each delay condition (1-Week, 2-Weeks, and 4-Weeks) to the latency in the first presentation, whilst also controlling for session effects (difference in control items across sessions). The full matrix for the contrasts is presented in Appendix E and are described in further detail below. The statistical package Multcomp (Hothorn et al., 2008) was then used to run one-way analyses on each comparison of interest. Holm-Bonferroni was used to correct for multiple comparisons. As in Experiment 1, accuracy data was fitted to a logistic mixed effects model (Accuracy ~ Condition + (1 | Subject) + (1 | Item)) ($\chi^2 = 2029.1$, $p < .001$), with the same contrasts across the conditions.

Results

The group mean and standard deviation response times are presented in Table 4 for each condition and presentation separately.

Table 4

Experiment 2: response latencies and error rates for each condition across the four sessions.

Condition	Session 1 (Day 1)	Session 2 (Day 8)	Session 3 (Day 15)	Session 4 (Day 29)
Response Latency (ms)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
1 Week	884.4 (287.0)	850.3 (229.9)	842.4 (252.5)	842.7 (233.4)
2 Weeks	885.8 (300.0)		867.2 (260.6)	853.7 (268.5)
4 Weeks	888.8 (295.6)			871.6 (253.2)
Control Session1	886.4 (304.9)			
Control Session2		891.1 (279.1)		
Control Session3			910.6 (300.1)	
Control Session4				910.0 (303.7)
Error Proportion				
1 Week	.034 (.18)	.025 (.16)	.015 (.12)	.017 (.15)
2 Weeks	.033 (.18)		.019 (.13)	.017 (.13)
4 Weeks	.042 (.20)			.024 (.15)
Control Session1	.024 (.15)			
Control Session2		.037 (.19)		
Control Session3			.025 (.16)	
Control Session4				.030 (.17)

Analysis 1: Priming effects and effects of prime-target delay. Figure 6 shows the first and second presentations at each lag along with the control items from the same sessions. As in Experiment 1, to determine whether individuals were faster to name items on the second presentation in each of the delay conditions, the difference in response latency between the first and second presentations was compared to the difference in the relevant controls. Significant priming was found in each delay condition, with on average, 39ms of priming for items repeated after one week, 43ms when repeated after two weeks and 41ms after four weeks (see Table 5).

There were no significant differences in the amount of priming for each delay condition controlling for differences in overall response time across sessions (see Table 5).

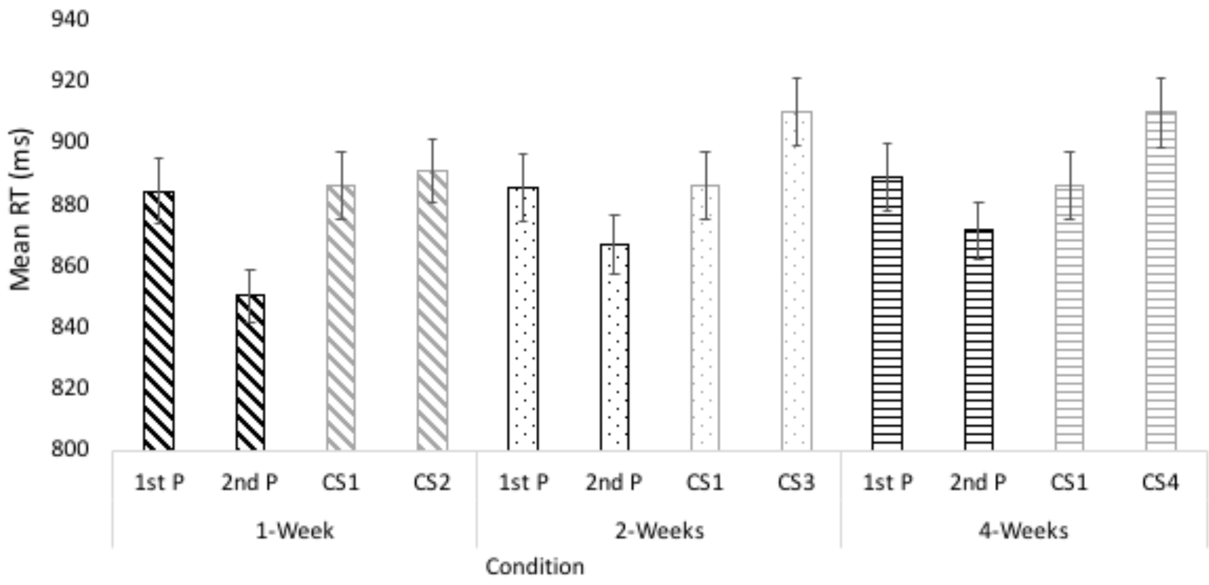

Figure 6. Experiment 2: Mean response times (RT) and standard error bars for the first presentation of items (unprimed), the second presentation of items (primed) compared to the control items from the same two sessions for each delay condition. 1st P = first presentation; 2nd P = second presentation; CS = Controls Session 1-4, displaying the control items from each of the four sessions. CS1 is used as the comparator for the session effect in Session 1, and is hence the same data in each plot.

Table 5

Experiment 2: Priming effect at each delay condition and comparisons between the three conditions for response latencies and accuracy

Contrasts	Estimate	Std. Error	z value	p value (Holm)
Response Latency Analyses				
Overall Priming Effect				
1-Week Priming	-.021	.007	-3.109	.006
2-Weeks Priming	-.020	.007	-2.989	.006
4-Weeks Priming	-.019	.007	-2.821	.006
Contrast Between Conditions				
1-Week vs 2-Weeks	-.002	.009	-.260	1
1-Week vs 4-Weeks	-.001	.009	-.129	1
2-Weeks vs 4-Weeks	-.001	.009	-.132	1
Error Analyses				
Overall Priming Effect				
1-Week Priming	.815	.465	1.752	.159
2-Weeks Priming	.699	.503	1.391	.164
4-Weeks Priming	.960	.466	2.059	.118
Contrast Between Conditions				
1-Week vs 2-Weeks	-.534	.666	-.802	.999
1-Week vs 4-Weeks	-.506	.646	-.784	.999
2-Weeks vs 4-Weeks	-.651	.673	-.968	.999

Analysis 2: Effects of Cumulative Presentation. The same analyses as Experiment 1 were performed to explore whether there was any additional benefit from repeating items more than once. The analysis looked within a session and determined whether there was a difference in the amount of priming based on how many presentations had occurred. For example, in Session 3, the amount of priming from the third presentations of 1-Week items was compared to the amount of priming from the second presentation of 2-Weeks items. As these comparisons occur within sessions, control items are not required in the analyses to control for session effects.

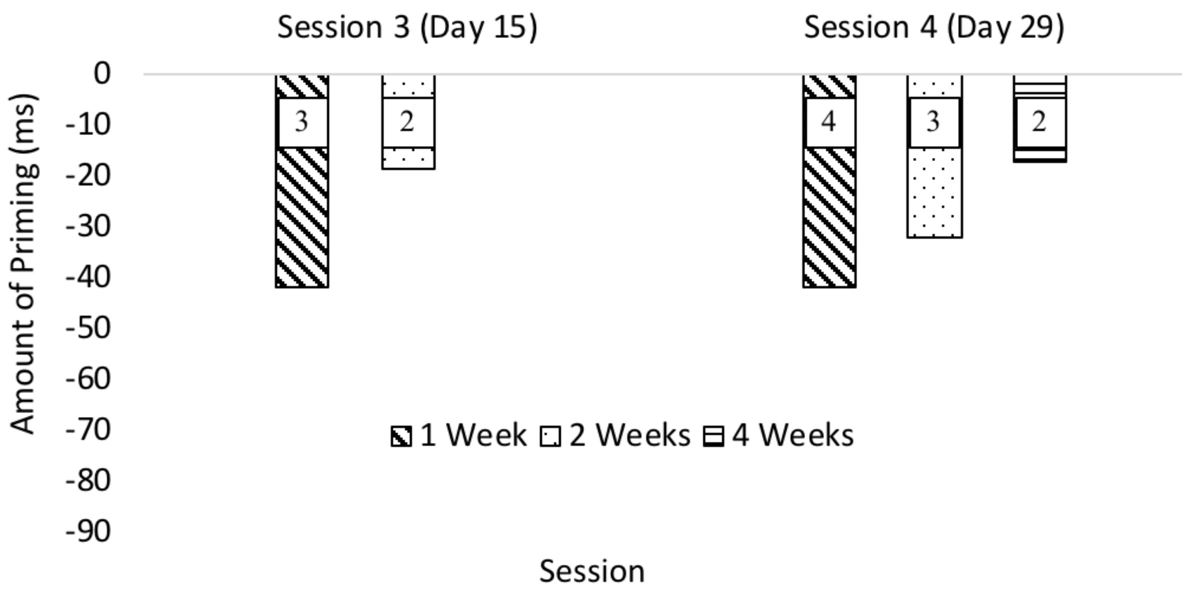

Figure 7. Experiment 2: Amount of priming between first presentation and repeated presentation in Sessions 3 and 4. Presentation number is displayed on the bars.

Figure 7 shows the average difference in latency between the first presentation and the repeated attempt for each presentation of the three target delays in Sessions 3 and 4. There were no significant differences in the amount of priming observed dependent on the number of repetitions of the target (see Table 6).

Table 6

Experiment 2: Results from comparisons of additional repetitions.

Contrasts	**Estimate**	**Std. Error**	**z value**	**p value (Holm)**
Response Latency Analyses				
Session 3: 1-Week3 vs 2-Weeks2 Priming	-.014	.007	-2.107	.140
Session 4: 1-Week4 vs 2-Weeks3 Priming	-.004	.007	-.605	.545
Session 4: 1-Week4 vs 4-Weeks2 Priming	-.013	.007	-1.901	.172
Session 4: 2-Weeks3 vs 4-Weeks2 Priming	-.009	.007	-1.299	.388
Error Analyses				
Session 3: 1-Week3 vs 2-Weeks2 Priming	.309	.523	.591	1
Session 4: 1-Week4 vs 2-Weeks3 Priming	.051	.515	.099	1
Session 4: 1-Week4 vs 4-Weeks2 Priming	.121	.484	.250	1
Session 4: 2-Weeks3 vs 4-Weeks2 Priming	.070	.484	.144	1

Experiment 2 Discussion

Experiment 2 examined the time course of priming across lags of one to four weeks. Different exemplars of pictures were used across repetitions in order to minimise any impact from more efficient visual identification. In addition, some targets were presented multiple times (but using different depicted exemplars) to determine the effects of stimulus repetition on priming. Significant priming effects were found on the first re-presentation of items at all intervals: one week, two weeks, and four weeks. Furthermore, the amount of priming was very consistent, with values of 39ms, 43ms and 41ms respectively, and no significant differences across lags. This indicates that between one and four weeks, priming effects do not appear to decay.

This stability of priming is consistent with previous studies using identical pictures. For example, Mitchell and Brown (1988) found priming of 70ms at one week, 71ms at four weeks, and 81ms at six weeks. Nevertheless, compared to Mitchell and Brown and other previous studies using identical pictures, we found reduced levels of priming, as we had in Experiment 1. For example, Cave (1997) found priming of 70ms at six weeks. These results replicate what we suggested on the basis of the results of Experiment 1, that previous studies of priming using identical pictures have had larger levels of priming due to visual priming effects. However, we have demonstrated that even when limiting visual effects, priming of word retrieval does occur long term, at least up to four weeks later.

General Discussion

The aim of this study was to explore the time course of repetition priming of word retrieval when visual priming effects are minimised. This was achieved in two picture naming experiments both of which examined priming when prime and target were represented by different exemplars of the same target (e.g. dogs: a collie and a labrador). Experiment 1 used three delays between prime and target: a few minutes (50 intervening items), one day, or one week. Experiment 2 investigated longer prime-target lags of one week, two weeks and four weeks. Significant priming was found at all prime-target lag and the amount of priming was similar at one week across both experiments. Whilst longer term priming has been demonstrated with the use of identical picture primes (e.g., Cave, 1997; Mitchell & Brown, 1988), to our knowledge, this is the first study to demonstrate priming beyond a lag of two days (Cave & Squire, 1992) using different pictorial exemplars.

As noted above, compared to previous studies using identical pictures at similar delay intervals, we found reduced levels of priming (see Figure 8). This suggests that at least some of the previously reported long-term priming was facilitated by visual priming, with a portion of the response time reduction having been due to visual processing efficiencies. As mentioned in the introduction, Cave and Squire (1992) found significant priming at a lag of two days, even when the picture had been manipulated in various ways, including by introducing a different exemplar. Interestingly, the way in which they manipulated the pictures also had a significant effect on the magnitude of priming, supporting a strong influence of visual similarity on priming. There was a significant difference between the items which were identical from the first session (996ms) and those that changed in exemplar (1051ms) as well as between identical pictures and those which had changed in shading (1031ms). However, there was no significant difference between identical items and those which had changed in size (1029ms). That we still found significant response time reductions in our study, demonstrates that language processing efficiencies must also be occurring.

Of course, there are other possible reasons contributing to variations in the amount of priming across studies. For example, participant characteristics such as age and/or education may influence results. Furthermore, some experimental factors such as the specific task, the time limit on naming responses and methods of data cleaning and analyses. This is discussed further in Chapter 4 (Creet et al., 2018c).

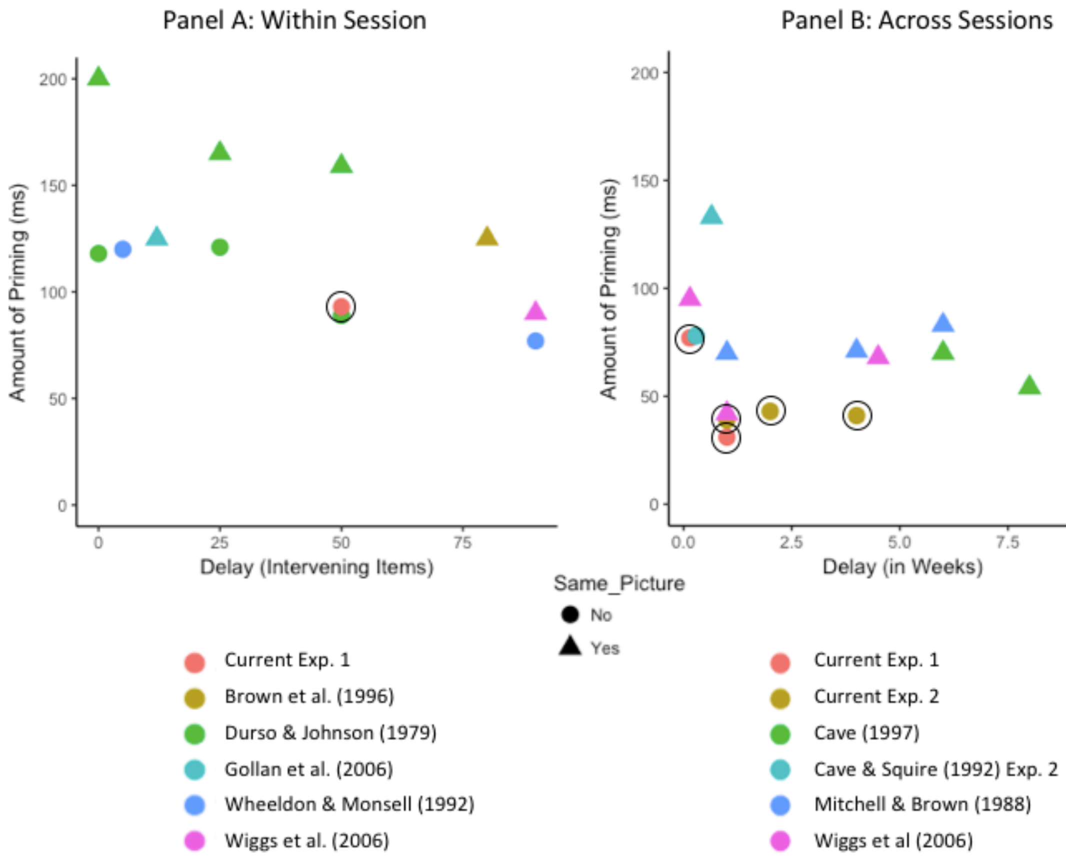

Figure 8. The amount of priming in milliseconds across repetition priming studies of picture naming. Note: where multiple measures were taken, an average is reported. Panel A displays within session repetitions, Panel B displays priming across separate sessions. The triangles represent identical prime-targets, whereas the filled circles represent a different prime-target. The results from the current experiments are ringed in black.

Our results clearly demonstrate that the changes in the efficiency of word retrieval are long lasting and, after some initial decline during the first week, remain fairly consistent over periods of one to four weeks. In Experiment 1 we found that average priming effects for the second presentation significantly declined at one week relative to the effects found within session or after one day. We initially hypothesised that the fact that previous studies using identical pictures had not shown this decline (e.g., Cave & Squire, 1992), perhaps indicated that visual priming was longer lasting than lexical priming. However, in our second experiment, no decay in priming was observed from one to four weeks. This suggests that any early decay of priming flattens to a stable level after one week. Further investigation is required to identify at what point priming effects are no longer evident. Cave (1997) found a reduced but still significant priming at 48 weeks, suggesting very slow decay. However, she used identical pictures, consequently it remains to be seen whether such long-term effects would be found with different exemplars.

In a review of repetition priming of picture naming, Francis (2014) concluded that priming was a result of long-term implicit learning, with all non-overlearned processes involved in both object identification and word production becoming faster as a result of repetition. We have argued that our experiments provide evidence for relatively long lasting priming of word production processes. However, of course, even with different exemplars, there is still visual similarity between the different pictures representing each target item. It has been proposed that there are separate subsystems involved in object recognition: one an abstract category subsystem (e.g., piano), and the other a specific exemplar subsystem (e.g., grand piano), which operate in parallel (Marsolek, 1999). In a study of visual priming, Biederman and Cooper (1991) manipulated aspects of line drawings and found that priming attributed to purely visual components was due to activation of a representation of the image's components and the specified relations of those components. When presented with the same picture, there is a complete overlap of these components and therefore assembling a representation of the components can be completed more easily. Mitchell (2006) argued that visual representations are subconsciously maintained over extremely long periods: He found significantly higher identification rates for fragments of pictures that were seen seventeen years prior, compared to fragments of pictures not seen before. The fact that visual effects can be so long lasting, creates some doubt of whether long term repetition priming studies are really tapping into priming of word retrieval and not faster picture identification (e.g., Cave, 1997). A future study could manipulate the degree of similarity between prime and target exemplars and examine its interaction with lag. In addition, an alternative mode of priming such as a naming to definition (cf Wheeldon & Monsell, 1992) could be used to further examine long-term lexical priming of word retrieval in picture naming. This could better discriminate the extent to which long-term effects are driven by visual or lexical priming mechanisms.

We did not aim to address at which point in the word production process repetition priming occurs. However, the results provide further support that priming of word retrieval is long lasting, supporting previous suggestions that facilitation occurs in the mapping from semantics to lexical form (e.g., Howard, Hickin, Redmond, Clark & Best, 2006; Wheeldon & Monsell, 1992; 1994).

Repetition priming has been shown to have a significantly greater effect on low frequency words (e.g., Wheeldon & Monsell, 1992) and later acquired words (Barry, Hirsh, Johnston & Williams, 2001). This interaction suggests that word accessibility and repetition priming have a common locus in the word production process. Wheeldon and Monsell (1992) proposed that the accessibility of high frequency words was due to the increased priming these words receive in everyday language compared to less frequently used words. If the level of priming was reducible to the number of repetitions, then cumulative priming effects might be predicted from each additional naming attempt. However, we found no significant increase in priming from additional repetitions of targets. This was true whether the additional repetition was a day earlier or a week earlier.

The combined finding of no significant cumulative effects of priming and the very long term priming effects up to four weeks after the initial prime presents a challenge to theories of priming effects in word retrieval. How does a single presentation have such a significant and enduring effect on a target word's accessibility, but further presentations do not? The simplest explanation for the lack of cumulative effects is that after one prime, target words reach their fastest response time, and no further benefit is possible with additional repetitions. That exactly one repetition should reach this fastest speed seems unlikely, especially given how variable response times are within individuals. Moreover, if picture naming is just another execution of target word production, why doesn't normal language use result in all items being at ceiling (and ‘unprimeable’)? Furthermore, it is likely that people have produced many of these words again between sessions and that, critically, this would include control items. Many of the target words are everyday items which are likely to come up in conversation within a month (e.g. fork, apple, car). Perhaps the picture naming task, which is not an everyday language task for adults, creates a novel language context and this context introduces a new association between the target word and the task scenario. While the specific stimulus has changed, as we are using a different exemplar, the experimental context remains constant. It is possible that there is enough visual similarity between the exemplars to generalise any task specific learning. Such an additional association may facilitate the lexical process and contribute to faster naming of repeated items. However, this cannot be the only mechanism driving priming given Wheeldon and Monsell’s (1992) finding that production in response to a definition primes later picture naming, at least within a session.

In summary, the experiments reported here provide the first demonstration that repetition priming effects in picture naming can be long lasting even when the pictures used are not identical and different exemplars are used. While short term priming can be explained by residual increased activation of the target word, the longer-term effects found here indicate that some durable cognitive change has occurred. These findings place a constraint on models of word production, which must explain the mechanisms by which long term increases in word accessibility occur. That such large increases in word accessibility can occur with a simple ‘intervention’ raises exciting possibilities for the treatment of populations with language impairment. If we can build on the research presented here to further understand the experimental and cognitive conditions under which these changes are realised, we may find new ways to harness priming in treatment programmes.

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Appendix A

Demographic information and memory test results for participants in Experiment 1

Participant	Sex	Age	Years of Education	Camden Memory (faces)	Digit Span
P01	Female	20	13	23	15
P02	Female	18	13	25	12
P03	Female	27	16	24	18
P04	Female	25	16	24	17
P05	Female	19	13	23	15
P06	Female	20	13	25	16
P07	Female	19	13	25	13
P08	Female	19	13	25	18
P09	Female	24	16	25	17
P10	Female	25	16	25	10
P11	Female	22	13	25	22
P12	Female	27	16	24	15
P13	Male	23	18	25	14
P14	Female	28	16	25	23
P15	Female	23	1	25	18
P16	Female	19	13	25	18
P17	Male	19	13	25	16
P18	Female	18	13	22	10
P19	Male	24	16	25	21
P20	Male	20	13	23	13
P21	Female	20	13	25	17
P22	Female	27	16	25	19
P23	Female	24	16	24	22
P24	Female	23	16	24	11

Appendix B

Demographic information and memory test results for participants in Experiment 2

Participant	Sex	Age	Years of Education	Camden Memory (faces)	Digit Span
P01	Female	21	13	24	24
P02	Male	19	13	25	15
P03	Female	21	13	25	12
P04	Male	19	13	25	22
P05	Female	21	13	25	16
P06	Male	27	19	25	23
P07	Female	21	13	25	15
P08	Female	19	13	25	16
P09	Female	19	13	25	14
P10	Female	22	19	25	21
P11	Male	22	19	25	18
P12	Female	21	13	23	12
P13	Female	30	18	25	17
P14	Male	28	19	24	18
P15	Female	19	13	23	13
P16	Male	22	13	23	23
P17	Female	25	16	24	18
P18	Male	29	16	23	19
P19	Male	21	16	21	17
P20	Male	25	16	23	23
P21	Female	21	13	23	22
P22	Female	29	14	23	9
P23	Female	30	16	25	20
P24	Male	24	13	25	21
P25	Female	22	17	23	17
P26	Female	18	13	24	10
P27	Female	23	13	22	14
P28	Female	20	13	25	18

Appendix C

List of stimuli used in Experiment 1 and 2.

Note: * indicates the three target items which were not used in Experiment 2.

anchor
angel
apple
balloon
banana
basket
bat
bath
battery
bear
bed
bell
belt
book
bowl
brain
bride
bridge
bucket
butterfly
button
cactus
cake
camel
camera
candle
car
carrot
cat
chain
chair
cheese
chimney
chocolate
church
clock
clown
coffin
comb
cork
cot
cow
crab
cucumber
cushion*
dart
desk*
die
doctor
dog
doll
donkey
door
dress
drum
duck
ear
egg
elephant
eye
fan
feather
fence
fish
flag
fly
foot
fork
fountain
fox
frog
giraffe
glasses
globe
glove
grapes
grass
grater
hammer
hammock
hand
harp
hook
horse
house
iron
jar
jug
kangaroo
kettle
key
kite
knife
koala
ladder
lamp
leaf
leg
lemon
lettuce
lion
magnet
mask
microphone
mirror
mop
mushroom
necklace
net
onion
orange
owl
pear
pen
pencil
penguin
piano
pineapple
pipe
pizza
plate
potato
pram
pumpkin

rabbit
rake
razor
ring
ruler
saddle
sandwich
saw
saxophone
scales
scarf
scissors
screw
shark
sheep
shell
shoe
sink
skeleton
skirt
slide
slipper
snail
snake
soap
sock
soldier*
spider
squirrel
stapler
starfish
stethoscope
stool
strawberry
swing
sword
table
tank
teapot
telescope
tent
tie
tiger
toaster
toilet
tomato
torch
towel
train
tray
tree
tweezers
tyre
umbrella
vase
violin
wallet
watch
wheelchair
whisk
whistle
window
witch
wreath
worm
yoyo
zebra
zip

Appendix D

Contrast Vectors for Experiment 1

Main Priming Effect:	**Min1**	**Min2**	**Day1**	**Day2**	**Week1**	**Week2**	**CS1a**	**CS1b**	**CS2**	**CS3**	**Min3**	**Min4**	**Day3**
Contrast	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Minutes priming (controlling for practice effect)	-1	1	0	0	0	0	1	-1	0	0	0	0	0
Day priming (controlling for practice effect)	0	0	-1	1	1	0	0	0	-1	0	0	0	0
week priming (controlling for practice effect)	0	0	1	0	-1	1	0	0	0	-1	0	0	0
Comparisons of Priming Conditions:	**Min1**	**Min2**	**Day1**	**Day2**	**Week1**	**Week2**	**CS1a**	**CS1b**	**CS2**	**CS3**	**Min3**	**Min4**	**Day3**
Min v Day priming (controlling for session effects)	-1	1	1	-1	-1	0	1	-1	1	0	0	0	0
min v week (controlling for session effects)	-1	1	-1	0	1	-1	1	-1	0	1	0	0	0
day v week (controlling for session effects)	1	0	-1	1	1	-1	-0.5	-0.5	-1	1	0	0	0
Cumulative Priming:	**Min1**	**Min2**	**Day1**	**Day2**	**Week1**	**Week2**	**CS1a**	**CS1b**	**CS2**	**CS3**	**Min3**	**Min4**	**Day3**
Min 3 v Day 2	-1	0	1	-1	0	0	0	0	0	0	1	0	0
Min 4 v Day 3	-1	0	1	0	0	0	0	0	0	0	0	1	-1
Min 4 v Week 2	-1	0	0	0	1	-1	0	0	0	0	0	1	0
Day 3 v Week 2	0	0	-1	0	1	-1	0	0	0	0	0	0	1

Appendix E

Contrast vectors for Experiment 2

Main Priming Effect:	**1-Week 1**	**1-Week 2**	**2-Weeks 1**	**2-Weeks 2**	**4-Weeks 1**	**4-Weeks 2**	**CS1**	**CS2**	**CS3**	**CS4**	**1-Week 3**	**1-Week 4**	**2-Weeks 3**
Contrast	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Week-1 Priming (controlling for session effects)	-1	1	0	0	0	0	1	-1	0	0	0	0	0
Week-2 Priming (controlling for session effects)	0	0	-1	1	0	0	1	0	-1	0	0	0	0
Week-4 Priming (controlling for session effects)	0	0	0	0	-1	1	1	0	0	-1	0	0	0
Comparison of Priming Conditions:	**1-Week 1**	**1-Week 2**	**2-Weeks 1**	**2-Weeks 2**	**4-Weeks 1**	**4-Weeks 2**	**CntS1**	**CntS2**	**CntS3**	**CntS4**	**1-Week 3**	**1-Week 4**	**2-Weeks 3**
1-Week v 2-Weeks priming (controlling for session effects)	-1	1	1	-1	1	0	-1	-1	1	0	0	0	0
1-Week v 4-Weeks Priming (controlling for session effects)	-1	1	1	0	1	-1	-1	-1	0	1	0	0	0
2-Weeks v 4-Weeks Priming (controlling for session effects)	1	0	-1	1	1	-1	-1	0	-1	1	0	0	0

Cumulative Priming :	**1-Week 1**	**1-Week 2**	**2-Weeks 1**	**2-Weeks 2**	**4-Weeks 1**	**4-Weeks 2**	**CS1**	**CS2**	**CS3**	**CS4**	**1-Week 3**	**1-Week 4**	**2-Weeks 3**
1-Week 3 v 1-Week 2	0	-1	0	0	0	0	0	1	-1	0	1	0	0
2-Weeks 3 v 2-Weeks 2	0	0	0	-1	0	0	0	0	1	-1	0	0	1
1-Week 4 v 1-Week 3	0	0	0	0	0	0	0	0	1	-1	-1	1	0

Chapter 4 (Paper 3)

Repetition priming of spoken word production in older adults

Abstract

Older adults are generally slower and more error prone in picture naming tasks compared to young adults. While both young and older adults are faster to name an item having named it previously, there are conflicting results in the literature regarding whether there are age differences in this repetition priming of word retrieval. The current study explored repetition priming of picture naming in older adults and compared their priming patterns to those of young adults.

Twenty-four older adults named six sets of 32 items across three sessions. Target items were repeated for naming (using different exemplars) either within a session (approximately 50 intervening items) or with one day, or one week lags between presentations. Priming was analysed using linear mixed effects modelling with contrast coding to compare the latency of the first and second presentation of a target while controlling for effects of session. Significant priming of word retrieval was found both within session and one day later. Priming was no longer significant at one week, although there were no significant differences in the extent of priming across lags. Compared to young adults who had completed the same task in a previous study, there was no evidence of significant age-related differences in the amount of priming for word retrieval, whether analysed as raw differences or proportional differences in response latencies. This study is the first to examine priming of word production at the individual level in unimpaired populations, and finds that priming was extremely variable both within and between individuals. Several cognitive factors are explored, but none significantly correlated with these individual priming effects. These results challenge the reliability of generalising from the group results to the individual.

Introduction

Ageing is associated with a slowing in cognitive processes and older adults show lower levels of performance in tasks involving short term memory, working memory, reasoning and spatial skills (Myerson, Hale, Wagstaff, Poon & Smith, 1990; Salthouse, 1996). In the area of language, the findings are mixed regarding the effects of age. For example, while vocabulary increases (Verhaeghen, 2003), word retrieval has been found to worsen with age (Burke, Mackay, Worthley & Wade, 1991; Nicholas, Obler, Albert & Goodglass, 1985). Here we focus on the effects of ageing on spoken word retrieval, and priming of this process in particular.

Older adults are more likely to experience difficulties in producing the correct name for an object or person while speaking, despite knowing the name in other contexts (Burke & Laver, 1990). Older participants also tend to be slower in picture naming and produce more errors (Burke et al., 1991; Mitchell, 1989; Nicholas et al., 1985). In their review of the effects of ageing on word production, Shafto and Taylor (2014) concluded that phonological access in particular weakened with age. Burke et al. (1991) found that elderly participants produced more tip of the tongue episodes: where the to-be-recalled word is known but not immediately recalled. They proposed that this was most likely due to weakened connections between lexical and phonological representations of words, due to three main factors: infrequent use, non-recent use and general ageing (see also Mackay & Burke, 1990).

One area where there is not to be clear age-related decline is repetition priming – where prior exposure to an item increases an individual's performance in a task involving that item even when the individual is unaware of the prior exposure. In a meta-analysis of thirty-six priming studies, primarily lexical decision and word completion studies, La Voie and Light (1994) found conflicting results regarding whether or not any age-related effects were evident in priming between the individual studies. Overall, they identified a slight decrease in priming effects for older participants. However, the age-related difference was larger for measures of explicit memory, with older adults having poorer recall and recognition, suggesting that there was some sparing of priming on more implicit measures. Laver and Burke (1993) performed a meta-analysis of fifteen studies of semantic priming, where semantically related information is provided (e.g., a category name prior to a lexical decision; Burke, White & Diaz, 1987). They found a significant *increase* in priming for older participants. This was interpreted as a result of largely intact semantic networks, which were activated by the prime, compensating for weaker connections to the phonological word form with ageing. Priming was suggested to provide additional activation to improve speed and accuracy of target word access.

To date, there are only a few studies of repetition priming of picture naming that have examined age differences. Mitchell, Brown and Murphy (1990) compared repetition priming of picture naming for older participants (mean age of 71) compared to young adults (mean age of 20) at lags of within session, one day, one week and three weeks. Older participants were slower at naming overall and made more errors. Both young and old had significant priming at all lags (measured by comparing primed items with control items) but this was significantly higher within session, dropping at one day and remaining fairly consistent through to three weeks. Critically, while the average amount of priming was slightly lower for older subjects this did not reach significance.

Using a similar design (and the longest lag extended to one month), Wiggs, Weisberg and Martin (2006) looked at repetition priming delays of within session, one day, one week and one month, across three age groups: young adults (20-38), young-elderly (65-74), and old-elderly (75-84). They found that all age groups showed significant priming at all delays. However, in contrast to Mitchell et al., there were differences between the young and elderly groups: the two elderly groups showed a drop in the magnitude of priming just one day later, whereas the young adults' priming remained fairly stable until one week.

Wingfield, Brownell and Hoyte (2006) looked at cumulative priming effects with five presentations of each item within a single session in young adults (17-22) and older adults (67-83). Participants were provided with the target response on any incorrect trials. Analyses examined the linear trend as opposed to overall priming: They found a main effect of age, as older adults were slower; and a main effect of trial, as both groups got progressively faster. However, there was no interaction with age and trial, suggesting similar trends between the two groups.

Finally, Maylor (1998) examined priming of naming of famous people comparing subjects in their 50s and 60s with an older group in their 70s and 80s. They found the older group made more errors or incomplete naming (surname only) but showed a similar pattern of improvement with picture repetition over a short interval - within session. Re-testing 22 months later, however, showed significant differences with the younger group showing greater accuracy for repeated faces over new faces, while the older group did not.

Given the conflicting results in the literature, it is important to further investigate the nature and extent of age differences in repetition priming of picture naming, both in the short and longer term in order that we can gain a better understanding of the time course of priming and how it relates to ageing. This is the aim of the current study. We use a picture naming paradigm to enable comparison with the findings of Mitchell et al. (1990) and Wiggs et al. (2006). Both Mitchell et al. (1990) and Wiggs et al. (2006) found that while both young and older participants showed a decline in recognition accuracy as the delay increased, older participants were less accurate at all delays. However, this difference in explicit visual memory did not translate to significant differences in implicit repetition priming.

While picture naming provides a direct prompt for the retrieval and production of a word based on semantic input, it clearly involves visual perceptual processing which will have an impact both on response times and priming (Francis, 2014). Visual processing deficits could contribute to slower response times in older participants, however, considering differences in neural-activity (using an Event-Related Potential methodology) suggests that differences in the time course of visual processing with age are negligible (Neumann, Obler, Gomes & Shafer, 2009). There is also the possibility that the visual processing of a repeat image is also primed, and this visual priming is differently affected with age. In previous studies examining effects of ageing on priming of picture naming, prime and target have used identical exemplars, in the current study, different exemplars of items are used to try and minimise any visual benefit and tap more directly into word retrieval processes.

Differences in priming patterns shown by older adults were examined across three delays: several minutes within the same session, one day, and one week. To examine the effects of ageing on priming, these data were also compared with the performance of young adults under the same conditions who showed significant priming in all three delay conditions despite the use of different exemplars. The data of the young adults was previously presented in Creet, Morris, Robidoux, Howard and Nickels (2018b).

Given the evidence that repetition priming effects dissociate from decline in episodic memory, the question remains as to whether other cognitive capacities are associated with an individual's ability to benefit from priming. It is possible that the mechanism(s) underpinning repetition priming require certain cognitive skills to be intact. For example, performance on a task that is commonly thought to involve executive functioning (Modified Wisconsin Card Sorting Task: Schretlen, 2010) was found to be associated with priming of naming accuracy for some individuals with language impairment and high error rates (Creet, Morris, Howard & Nickels, 2018a). Hence, we also investigated potential cognitive factors underpinning individual variation in priming in ageing.

General Method

Participants

Participants were native speakers of British English with normal or corrected to normal vision and hearing, reporting no learning difficulties or neurological damage. Twenty-four older adult participants (14 female) were recruited through a community group. Participants were aged between 58 and 85 years (mean: 71.1; SD: 5.9), and were predominantly highly educated with 79% having completed further or higher education. Also reported are the data from Creet et al. (2018b) which included twenty-four (20 female) young adults (university students) who were recruited through Newcastle University, UK, and aged between 18 and 28 years (mean: 22.2; SD: 3.2).

Cognitive tests

Older adult participants completed a range of cognitive assessments to explore the potential cognitive underpinnings of repetition priming.

The Verbal Fluency Test from the Comprehensive Aphasia Test (CAT subtest 3; Swinburn, Porter & Howard, 2004) instructs participants to name as many words as possible of a particular category (animals) and then as many words beginning with a certain letter (s) in one minute. This assesses language skills, as well as cognitive flexibility and working memory.

The Birmingham Cognitive Screen (BCoS) sustained attention task (Humphreys, Bickerton, Samson & Riddoch, 2012) involves listening to a string of six different words and tapping on the table when one of a set of target words occurs (‘hello’ ‘please’ and ‘no’), ignoring distractor words (‘goodbye’ ‘thanks’ and ‘yes’). This task aims to assess sustained attention, selective attention and working memory as well as inhibition of the related distractor words.

The Modified Wisconsin Card Sorting Test (M-WCST; Schretlen, 2010) is a card sorting task which requires participants to sort cards in one of four piles according to a rule which they must figure out by trial and error (either colour, number or shape). After successfully following the rule for six consecutive turns, the rule changes again and a different rule mist be discovered and followed. The task is designed to assess executive functioning: involving rule discovery and following, task switching, working memory and inhibition (of previous rules). All participants also completed two memory tests: the Camden Short Memory Test for Faces (Warrington, 1996) which has participants see 25 faces where they have to judge whether the person looks pleasant or not. They then are re-presented with each of those faces next to a new face, with instructions to point to the face they have seen already. This task tests visual memory.

The Wechsler Forwards and Backwards Digit Span (Wechsler, 1987) requires participants to repeat a string of numbers of increasing length (two each of three to eight digit strings) the experimenter has said aloud. When participants get both attempts at a string-length wrong, the test is discontinued. They then have to do the same (with different numbers), recalling the numbers in the reverse of the presentation order (strings of length two to seven). This task is a measure of working memory, with a maximum score of 24.

Table 1

Older adult participants' demographics and cognitive test information.

Scores outside of normative values are ***bolded.***

Participant	Age	Sex	Years of Education	Episodic Memory (Faces)	Forward Digit Span Test Score	Sustained Attention	M-WCST standard score	Fluency: Category	Fluency: Letter
Max Score				25	24	100	-	NA	NA
Norm Cut off				18	5	-	80	14	14
O1	85	Female	13	22	19	100%	126	22	25
O2	75	Male	15	23	14	100%	95	19	25
O3	72	Male	13	24	23	100%	98	18	14
O4	66	Female	16	25	15	100%	122	28	20
O5	74	Male	16	20	17	100%	84	17	23
O6	63	Female	15	22	17	100%	110	21	26
O7	67	Female	13	24	24	100%	83	15	20
O8	71	Male	15	23	16	100%	94	**13**	15
O9	71	Female	18	22	17	98%	114	17	21
O10	69	Female	12	25	24	100%	116	18	16
O11	69	Male	18	25	20	100%	98	18	18
O12	71	Female	20	24	19	100%	101	19	22
O13	66	Female	13	25	17	100%	116	23	16
O14	75	Female	15	24	23	100%	121	26	15
O15	65	Female	16	25	16	100%	107	27	18
O16	74	Female	12	24	17	100%	**70**	34	22
O17	81	Male	18	25	14	100%	130	17	20
O18	72	Male	16	22	18	100%	119	25	23
O19	73	Female	18	23	16	87%	**69**	15	15
O20	81	Male	20	24	23	100%	114	25	21
O21	69	Male	17	24	15	100%	104	15	22
O22	71	Female	16	24	20	100%	80	24	16
O23	69	Male	16	24	18	100%	106	25	18
O24	58	Female	14	24	15	100%	108	25	23
Average	71.1	58% female	15.6	23.6	18.2	99%	103.5	21.1	19.8
SD	5.9		2.3	1.3	3.2	.03	16.9	5.2	3.6

Materials

Stimuli were 882 coloured photographs depicting single objects on a plain white background (see Creet et al., 2018b) for more information). Targets comprised 192 items that had four different depictions which had name agreement above 90% (Creet et al., 2018b). These items were divided into six sets of 32 items matched on name agreement, spoken word (log) frequency (van Heuven, Mandera, Keuleers & Brysbaert, 2014), length in phonemes and syllables (Davis, 2005), age of acquisition (Kuperman, Stadthagen-Gonzalez & Brysbaert, 2012), concreteness (Brysbaert, Warriner, & Kuperman, 2014) and visual complexity (as indicated by file size (Székely & Bates, 2000)). These sets were then assigned to six conditions, counterbalancing such that every set appeared in every condition an equal number of times. This counterbalancing resulted in 24 versions of the experiment. The remaining 114 pictures were selected to act as fillers.

Procedure

Participants were tested individually at Newcastle University using the experimental software DMDX (Forster & Forster, 2003). Participants were given both written and verbal instructions explaining that they would see pictures of single items, which they would be required to name aloud as quickly and accurately as possible. They were informed that some items might appear more than once so not to hesitate to say a name again. Each trial began with a fixation cross for 250ms, followed by a target picture, which remained until the participant made their response and the trial was manually terminated, or for a maximum of 5000ms (see Figure 1). A blank screen then appeared for 500ms before automatically moving on to the next trial. Each session consisted of 165 items and lasted approximately 10 minutes.

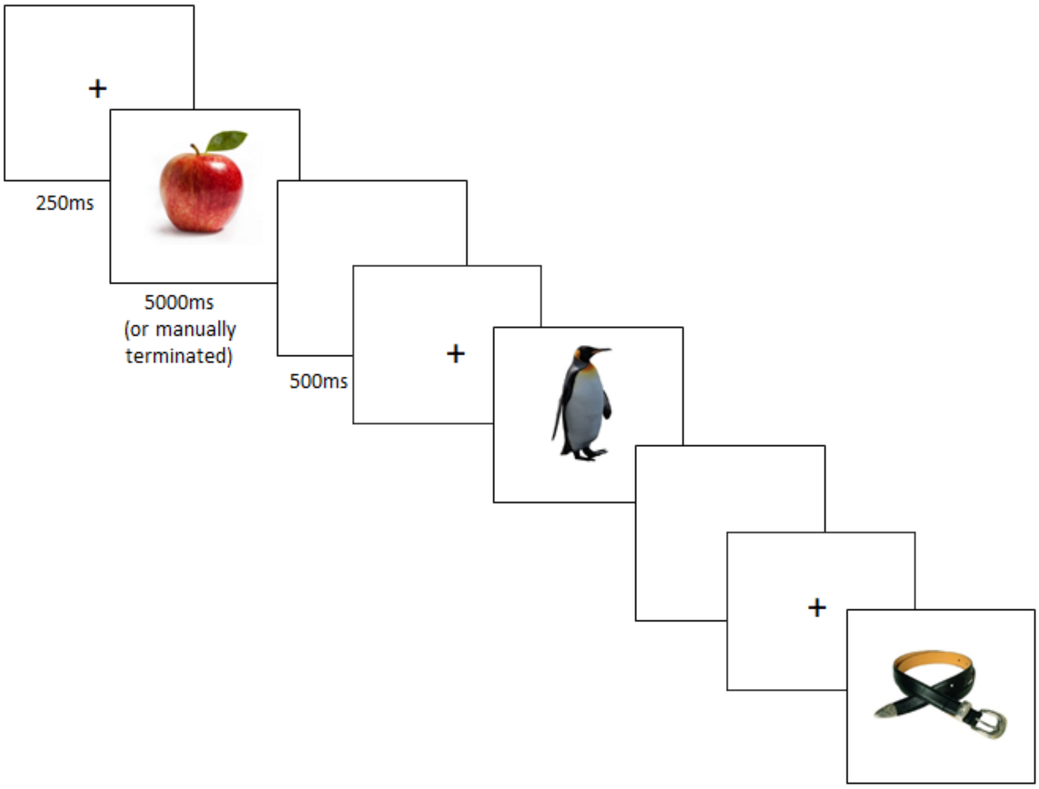

Figure 1. An example of the experimental sequence.

Participants were tested in three sessions over three different days. This provided three time lags for repetition priming (see Figure 2): a lag of several minutes within Session 1 (Minutes), a lag of one day on Session 2 (Day), and a lag of one week on Session 3 (Week). On Day 1, sets assigned to all three target delay conditions were presented for the first time (Minutes, Day, Week) as well as the control set 'Control Session 1'. The Minutes items were presented for the second time within the session, separated by approximately 50 items from the first presentation (whilst ensuring that target items did not appear in the same consecutive order). On Day 2, the items in the Day priming condition were presented for the second time, and Control Session 2 items for the first (and only) time. In the third session, on Day 8, the Week items were presented for the second time, and Control Session 3 items for the first time. The Minutes items were also presented for a third time in Session 2 and Minutes and Day items for the fourth and third time respectively in Session 3, but these data are not analysed here. Unrepeated filler items were used to ensure that there were equal numbers of items to name each session.

Condition	Session 1 (Day 1)	Session 2 (Day 2)	Session 3 (Day 8)	Repetition Delay
Minutes	 Test 1  Test 2			minutes
Day	 Test 1	 Test 2		1 day
Week	 Test 1		 Test 2	1 week
Control				not repeated

Figure 2. A visual representation of the experimental design.

Response scoring

A response was marked as correct when the target name was produced within 5000ms, or when a close alternative name was given (e.g. *pushchair* for *pram*). However, to be considered correct, alternative names had to be used consistently when naming exemplars of that item across sessions. Only a participant's first attempt at an answer was scored, with the exception of production of a single phoneme before a full attempt (e.g., *s...pram* was considered correct) in which case the response time was measured from the start of the completed word (/p/ in the pram example).

Data analysis

Wave forms and spectrograms for each response were examined using CheckVocal (Protopapas, 2007). Each response was coded as correct or incorrect, and response latencies were adjusted as necessary to compensate for microphone errors. These data were then analysed in R-Studio (R Core Team, 2013). Incorrect responses were removed from the response time analyses. Any responses taking longer than 3000ms (28 trials) were also removed following visual inspection of potential outliers. To improve normality of the model residuals and to meet the assumptions of mixed effects modelling, a logarithmic transformation was used. Further information on the specific analyses used are presented in the relevant results sections.

Results

Analysis 1: Overall Effects of Priming for the Group of Older Adults

The first analysis of interest was whether the older adults showed priming effects: whether participants were faster/more accurate to name items on the second occasion in each of the three delay conditions.

The mean and standard deviation response latencies and the proportion of errors are presented in Table 2 for each delay condition and presentation number separately, together with the young adults' data for comparison.

Response Latency. The amount of priming for each delay condition was calculated by looking at the difference between first and second presentations, minus any difference across the control sessions in the same two sessions. For older adults this resulted in average priming of: Minutes: 108ms; Day: 47ms; Week: 37ms, and for young adults: Minutes: 93ms; Day: 77ms; Week: 31ms.

Table 2

Response times and errors for each condition in the first and second presentations. The amount of priming is the difference between the two presentations in milliseconds, whilst controlling for session effects (difference between control items).

	Older Adults			Young Adults		
Condition **RT (ms)**	**Presentation 1 (Unprimed) Mean (SD)**	**Presentation 2 (Primed) Mean (SD)**	**Priming (ms) Mean (SD)**	**Presentation 1 (Unprimed) Mean (SD)**	**Presentation 2 (Primed) Mean (SD)**	**Priming (ms) Mean (SD)**
Minutes	960.1 (312.9)	878.2 (233.0)	-107.9 (113)	772.9 (259.7)	694.7 (177.1)	-93.4 (74.6)
Day	950.1 (270.6)	898.5 (254.9)	-47.2 (90.6)	773.6 (247.6)	699.8 (174.8)	-77.5 (59.3)
Week	951.0 (299.5)	940.9 (273.4)	-37.1 (95.0)	763.5 (233.7)	722.5 (192.1)	-31.1 (61.3)
Control S1	964.2 (308.1)			776.1 (238.9)		
Control S2	946.6 (286.3)			767.2 (239.4)		
Control S3	977.0 (334.1)			763.6 (248.6)		
Error Proportion	**Presentation 1 (Unprimed)**	**Presentation 2 (Primed)**	**Priming**	**Presentation 1 (Unprimed)**	**Presentation 2 (Primed)**	**Priming**
Minutes	.033 (.033)	.025 (.029)	-.021 (.048)	.031 (.026)	.017 (.023)	-.030 (.070)
Day	.038 (.038)	.022 (.025)	-.017 (.071)	.023 (.036)	.012 (.020)	-.007 (.053)
Week	.030 (.037)	.030 (.034)	.012 (.053)	.029 (.034)	.020 (.034)	-.008 (.065)
Control S1	.027 (.034)			.026 (.033)		
Control S2	.031 (.039)			.023 (.030)		
Control S3	.026 (.035)			.022 (.022)		

Linear mixed effects models were constructed, using the lme4 package (Bates, Maechler, Bolker & Walker, 2015), to examine the effect of Condition (time delay and presentation number, e.g., first presentation of day condition) on response times. The dependent variable was log RT, with presentation number and time delay as fixed effects. As random effects, the model included intercepts for subjects and items (LogRT ~ Condition + (1 |Subject) + (1 |Item). Barr, Levy, Scheepers and Tily (2013) have proposed that researchers should always fit the maximal random structure whenever possible. Accordingly, we first entered by-subject and by-item random slopes for condition, however, the model failed to converge. The model showed a clear influence of Condition on the logRT (χ^2 (1,16) = 1998.5, $p < .001$).

Contrast coding was then used to compare the difference in RT from first to the second presentation. It is possible that RTs would get faster due to practice effects. To account for these, we compared the difference for the critical items to the difference in two relevant control sets across the sessions. For example, to examine the priming effect over one day, we compared the difference in RTs from the Day items in Session 1 to the Day items in Session 2 (the sheep in Figure 2), to the same difference between the control items of Sessions 1 and 2 (the bowl and key at the bottom of Figure 2). The full set of contrasts for all of the tests described here appear in Appendix A. For the Minutes comparison, the control items for Session 1 were split in half (first half vs second half) for contrasts controlling whether there was any change in overall RT within the first session. The statistical package multcomp (Hothorn, Bretz & Westfall, 2008) was then used to test each contrast. Holm-Bonferroni was used to correct for multiple comparisons.

Whether there was a significant difference in the amount of priming at different delay conditions was examined by comparing whether the difference from first to second presentation versus the difference between the control conditions was greater for Minutes, Day or Week (See Appendix A for the contrasts).

As Table 3 shows, there was significant priming at lags of both minutes and one day between prime and target, but not at a lag of one week. However, there were no significant differences found in the amount of priming across lags for the older adults, although the difference between the shortest (minutes) and longest (week) prime-target lag was close to significant (p = .061), leaving conclusions for that condition ambiguous.

Table 3

Model output examining priming in each delay condition, controlling for session effects, and comparisons of these priming effects (all p values corrected using Holm-Bonferroni corrections for 3 tests) for older adults.

Contrasts	**Estimate**	**Std. Error**	**z value**	**p value (Holm)**
Response Latency (ms)				
Overall Priming Effect:				
Minutes Priming	-.034	.008	-4.233	**<.000**
Day Priming	-.023	.006	-3.514	**<.001**
Week Priming	-.010	.006	-1.591	.112
Comparison between delay conditions:				
Minutes vs Day Priming	-.012	.010	-1.119	.296
Minutes vs Week Priming	-.024	.010	-2.318	*.061*
Day vs Week Priming	-.013	.009	-1.446	.296
Accuracy (Error Proportion)	**Estimate**	**Std. Error**	**z value**	**p value (Holm)**
Overall Priming Effect:				
Minutes Priming	.622	.589	1.055	.583
Day Priming	.678	.450	1.506	.396
Week Priming	-.425	.444	-.957	.583
Comparison between delay conditions:				
Minutes vs Day Priming	-.056	.742	-.076	.940
Minutes vs Week Priming	1.047	.738	1.418	.469
Day vs Week Priming	.529	.643	.823	.821

Accuracy. For accuracy data, a logistic mixed effects model was fitted (Accuracy ~ Condition + (1 | Subject) + (1 |Item)) (χ^2 (1,15) =71.7, p < .001); suggesting that Condition influenced accuracy. The same contrast coding was then used for all analyses to compare the conditions of interest. Priming was evaluated by comparing the difference between first and second presentations of items, minus any difference between the two sets of control (unrepeated) stimuli from the same two sessions to control for effects of session. There were no significant priming effects on accuracy (see Table 3).

Analysis 2: Comparison of Priming across Young and Older Adults.

A second question of interest was whether there were any differences in priming effects between the young and older adults. This was examined by including both groups of participants in the same analysis with an interaction term for age group.

Response Latency. Model comparison was performed between the original model (LogRT ~ CondLevel + (1|Subject) + (1|Item)) and one with an added main effect of Age Group (LogRT ~ CondLevel + AgeGroup + (1|Subject) + (1|Item)). A significant main effect of Age was found, indicating that there are some differences in latencies between the older and younger adults (χ^2 (1,17) = 40.909, p <.001). Further model comparisons were made with this improved model and a new model including an interaction term between age and condition (LogRT ~ CondLevel * AgeGroup + (1|Subject) + (1|Item)). The model which included the interaction term was a significantly better fit for latency indicating that there were significant differences in the pattern of reaction times between the two groups (χ^2 (12, 29) = 29.808, p < .001; see Table 2 earlier and Figure 3). Contrasts analyses are required to see if there are differences in the amount of priming between the two age groups.

Accuracy. The interaction term was also examined for accuracy data. While including the main effect of Age Group improved the fit of the model, this was not significant (χ^2 (1,17) = 1.172, p =.279). Similarly, including the interaction term of Age Group and

Condition was the best fit, this was also not significant (χ^2 (12, 29) = 5.33, p =.926). To examine any interactions of age group and priming, the package lsmeans (Lenth, 2016) was used to compare the conditions using similar contrasts to Analysis 1, with the addition of comparing the differences across the conditions between the two age groups (see Appendix B). The older adults were slower overall (as confirmed by the significant main effect of age group in the model), but there were no significant interactions with age and priming (Table 4). There were no significant interactions with accuracy and age group, nor between accuracy, age group and priming[3].

[3] To further rule out that there were no age effects of priming, these data were also submitted to an analysis of variance (ANOVA) with Age group and Delay as the main effects as well as the interaction term between the two. Two ANOVAs were run. Firstly, using each participant's mean priming measure (the difference in RT from 1st to 2nd presentation controlling for session effects. Secondly, using each participant's proportional priming measure (primed – baseline/baseline). Neither analysis produced a main effect of Age group or a significant interaction between Age and Delay (see Appendix C for the results).

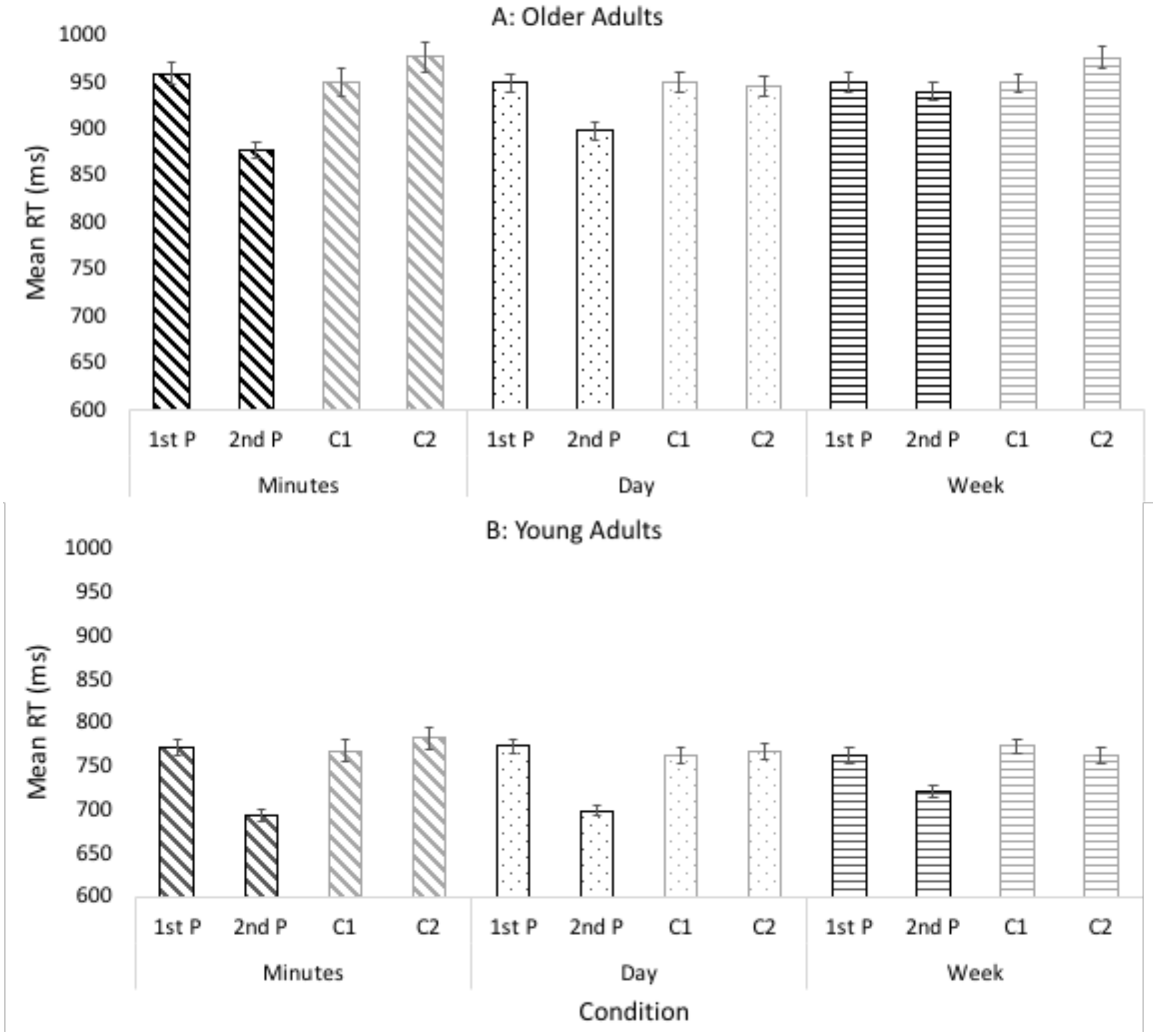

Figure 3. Mean response times (RT) and standard error bars for the first presentation of items (unprimed), the second presentation of items (primed) compared to the control items from the same two sessions for each delay condition for older (Panel A) and young (Panel B) adults. Note: 1st P = first presentation of targets; 2nd P = second presentation of targets; C1 = controls for first presentation of targets; C2 = controls for second presentation. Note that first control for Day is the first presentation of Week, and the first control for Week is the first presentation of Day.

Table 4

Model output for the interaction between priming and age groups

Contrasts	Estimate	Std. Error	df	t	p value (Holm)
Priming and Age interaction (Response Times)					
Overall Priming Effect:					
Minutes Priming	.003	.011	17660.09	0.259	.796
Day Priming	.016	.009	17660.08	1.752	.080
Week Priming	.005	.009	17660.21	0.562	.574
Comparison between delay conditions:					
Minutes vs Day Priming	-.013	.015	17660.17	-.908	.364
Minutes vs Week Priming	-.002	.015	17660.04	-.155	.877
Day vs Week Priming	-.009	.013	17660.06	.683	.495
Priming and Age interaction (Accuracy)					
Overall Priming Effect:					
Minutes Priming	-.009	.184	18192.25	-.496	.620
Day Priming	.010	.015	18192.25	.694	.488
Week Priming	-.020	.015	18192.25	-1.302	.193
Comparison between delay conditions:					
Minutes vs Day Priming	-.020	.024	18192.25	-.823	.410
Minutes vs Week Priming	.010	.024	18192.25	.439	.661
Day vs Week Priming	.017	.021	18192.25	.798	.425

Discussion Analyses 1 & 2

Older adults were significantly faster to name different depictions of objects on the second presentation a few minutes and one day later, controlling for effects of session. At a delay of one week, there was no longer significant priming. However, there were no significant differences between the different delays in the size of the priming effects.

This was in contrast to the young adults reported in Creet et al. (2018b) who showed significant priming at each time delay, but who also showed a significant difference between the shortest two lags (minute and day) and the longest lag (week). While this implies a potentially different pattern of priming between the young and older adult participants, in the analyses reported in this paper, there was no significant interaction between age group and priming at any delay condition. Older adults were, as expected, slower overall to name pictures than the young adults.

Analysis 3: Exploring factors influencing priming

This analysis aimed to examine whether there were individual factors that might underpin the degree of priming, with a focus on factors that have been associated with cognitive changes in ageing.

We first examined individual variability in priming effects. As shown in Figure 4, there was extensive apparent variability between individuals in the amount of priming (controlling for session effects). We first examined whether each individual showed significant priming effects by constructing a linear mixed effect model in R for each participant separately. The dependent variable was log RT, with condition as the fixed effect and Targets entered as random effects (Log RT ~ Condition + (1 |Target)).

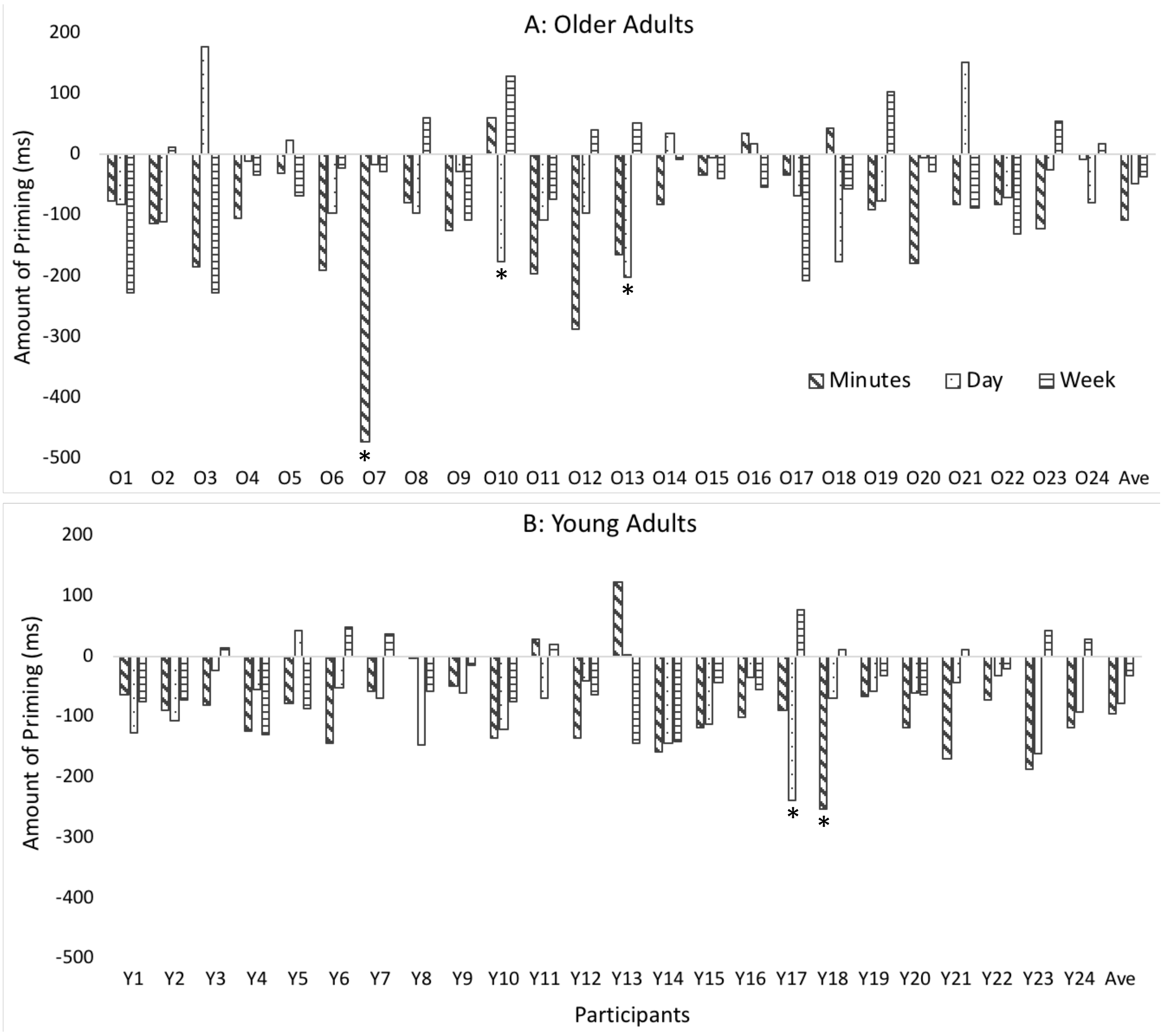

Figure 4. The amount of priming (controlling for session effects) for each participant individually for both the older and young adults. Ave: Average priming effect across the group. O: Older adult participant, and participant number. Y: Young adult participant and participant number. Asterisks indicate conditions where priming was significant for an individual.

The output from the linear mixed effects analyses for each individual in both age groups is presented in Appendix D. There were very few significant priming effects: For the older adults, participant O7 showed significant priming at the Minutes delay, with O10 and O13 displaying significant priming at the Day delay. For the young adults, Y18 had significant priming at the Minutes delay, and Y17 at one Day delay.

In order to determine whether any individual factors accounted for the variability in priming in the older adults, we examined the correlations between the participant's cognitive measures and the amount of priming in each of the three priming conditions. It is possible that general cognitive changes associated with ageing, might also reflect the same mechanism that is involved in priming. However, no correlation reached significance following correction for multiple comparisons (see Appendix E for the results). Moreover, priming at one lag did not correlate with priming at another time lag, indicating significant variability within individuals [Minutes * Day: $r(24) = .122$, $p = .571$; Minutes * Week: $r(24) = .013$, $p = .952$; Day * Week: $r(24) = .452$, $p = .027$ (note: due to multiple comparisons, p-value must be less than .005 to be significant)].

Discussion Analysis 3

There were few individuals who showed any significant priming. This is most likely due to lack of statistical power at the individual level. Nevertheless, this analysis did highlight the large individual variation both within and between participants. It appears that priming of lexical retrieval may not be as reliable as group results suggest. This problem of generalisability from group results to individuals has been found in other areas of social science (Fisher, Medaglia & Jeronimus, 2018). For example, in a study examining the reliability of semantic priming of lexical decision, Stoltz, Besner and Carr (2005) found that the effect was not consistent, with large variation both within and between participants. In our study, priming at one lag did not predict priming at another, further supporting the notion that priming may not be consistent within individuals. Since there was little consistency in the magnitude of the priming for individual subjects across conditions and lags, it is unsurprising that there were no specific cognitive factors which predicted the extent of priming at each time lag.

General Discussion

There were two main aims of this study. Firstly, to better understand the time course of repetition priming of word retrieval in older adults and how it differs from that of young adults, and to do so while reducing the influence of visual priming by using different exemplars of a target. Secondly, to examine priming at the individual level in order to establish how robust priming effects are in unimpaired speakers, and to see if there were any cognitive skills associated with priming.

At shorter delays between prime and target (within session and at one day) both the young and older adult groups displayed significant priming. However, at a longer delay of one week, priming was only significant for the young adults. Nevertheless, there were no significant interactions between priming and age group, nor between priming delay and age group. Investigation of this further at the individual level showed that there was considerable variation in the amount (or presence) of priming both within a participant at the different delays and between participants.

One important feature of our design is that we used different exemplars of each item at each presentation. For the older participants, the priming was weaker for the longer delays than in previous studies that used identical depictions at each presentation (e.g., Cave & Squire, 1992; Mitchell et al., 1990; Wiggs et al., 2006). For example, Cave and Squire (1992) reported priming of 133ms at a delay of two days for older adult participants, whereas our participants showed 47ms one day later. At one week our older adults showed 37ms of priming, compared to 55ms in Mitchell et al., (1990) and 51ms in Wiggs et al., (2006). This difference in the magnitude of priming can likely be attributed in part to our use of different exemplars for each presentation: Previous studies using identical pictures at both time points would almost certainly have been measuring visual priming in addition to priming of the word retrieval processes (Creet et al., 2018b).

We found no evidence that the older adults showed greater or lesser priming than young adults. This was true whether we examined raw or proportional priming. This replicates Mitchell et al. (1990) who found no age differences in priming using raw response latencies (primed item RTs compared to new controls). Wiggs et al. (2006) also concluded that priming appeared to be spared with age. They used proportional priming measures and found that there was no difference in the proportional magnitude of priming between the age groups. However, they did find a significant interaction between age and delay with older adults having a decline in the magnitude of priming earlier than young adults, we now discuss this in more detail.

Our results show a similar pattern of decline of priming over time to that found by Wiggs et al. (2006). As they did, we found that young adults' priming showed no significant decline from minutes to one day (our study: 93ms - 77ms; Wiggs et al. (2006) 90 ms-95ms) but had dropped significantly by one week (Our study: 31ms; Wiggs et al: 42ms). In contrast, the older adults had a steeper drop from minutes to one day (Our study: 108ms to 47 ms; Wiggs et al: 132ms to 48ms), remaining fairly stable one week later (Our study: 37ms; Wiggs et al.: 51ms). This is in contrast to Mitchell et al. (1990) who found both young and older individuals showed the greatest drop in priming from within session to one day. All three studies have relatively comparably aged participants (although the current study had a wider age range). Despite this group difference of where the largest drop in the magnitude of priming occurred, we did not find a significant interaction between group and lag. This is consistent with Mitchell et al. (1990), once again supporting the view there are not large age differences in the decay of priming.

Despite these similarities in findings, in contrast to our results, Wiggs et al. (2006) found that all age groups showed significant priming at a week and even at a one month delay (young: 68ms; older: 45ms). Mitchell et al. (1990) also found significant priming in both age groups at three weeks (older: 61ms; young: 55ms). There are a few methodological differences which could explain our lack of significant priming at one week. One possible reason that we did not observe priming at one week is that we used mixed effects models rather than analysis of variance (ANOVA). Mixed effects models can be a more robust form of analysis since they model each individual data point and account for the repetition of the items across participants. As we have seen from examining the individuals separately, there is wide variation in priming effects which can decrease power. In addition, in our analyses, we examined the difference in naming speed of the same items while controlling for session effects (using the differences in latency of novel control items at each session).

Whilst the field of psycholinguistics has moved towards linear mixed effects analysis as the best practice, in the interest of direct comparison to previous research we reran our analyses using ANOVA. Submitting the mean response latencies of the older controls to a 2 (primed/control) x 3 (delay) ANOVA, we found significant main effects of priming ($F(1,23) = 38.2$, $p < .001$) and delay ($F(1,23) = 5.2$, $p = .009$). However, unlike the mixed effects model analysis, we also found a significant interaction between priming and delay ($F(1,46) = 5.3$, $p = .009$). Critically, planned contrasts within each delay revealed priming was significant at each delay including the week delay that was not significant in the mixed effect modelling ($t(23) = 2.95$ $p = .004$).

There are multiple possible reasons for the difference in conclusions from the mixed effects modelling and ANOVA analyses. It could be that accounting for the item-level variance in the mixed effects modelling changes the results. It could also be due to controlling for practice effects (which is not included in the ANOVA). A third possibility is that moving from analysing the response times (RTs) in their original form to the log(RT) measure used in LME changes the results (Balota, Aschenbrenner, and Yap, 2013). Further research would be required to discriminate between these possibilities.

In addition, the difference between studies could be due to the fact that the previous studies used identical pictures, whereas our experiment used alternative exemplars of a target at each presentation. Perhaps with identical pictures, the one week delay may have been significant even using mixed effect modelling (as it was for young adults). Potentially at the longer delays, effects of priming found for older adults in previous studies may have been enhanced by visual priming processes and priming of word retrieval is more likely to have decayed. A future study could include some identical and some changed exemplars and use both methods of analysis to further clarify this.

Although it is clear that effects of repetition priming in word retrieval are not purely a result of visual processing (Wheeldon & Monsell, 1992) or episodic memory (Cave, 1997), this does not rule out some additional benefit through either of these mechanisms. Indeed, as discussed above, the reduced priming with different visual exemplars supports a potential role for visual priming. In terms of episodic memory, the fact that larger priming effects are found at the shortest intervals could indicate that there is some trace memory of the response, making it easier to retrieve the word the next time. At longer delays, this additional benefit has reduced but some priming remains from strengthening the connections between semantics and phonology. It is possible that the additional short-term benefit decays faster for older adults. Episodic memory has been found to decrease with age (e.g., Mitchell et al., 1990; Nilsson, 2003; Souchay, Isingrini & Espagnet, 2000; Wiggs et al., 2006). Therefore, any memory of the response that contributes to faster response times may degrade faster for older participants. Nevertheless, we did not find a correlation between episodic memory (as measured by the Camden Short Memory Test for Faces; Warrington, 1996) and extent of priming, casting doubt on this hypothesis.

Conclusion

Overall, this study found significant priming of word retrieval for older adults both within a single session and one day later. Priming was no longer evident at one week, although there was no evidence of a difference in the extent of priming across lags. This contrasts with the young adults who still showed significant priming at one week, nevertheless we found no interaction between age and priming at any time point (using raw or proportional priming). Therefore, we have little evidence of any age-related differences in the amount of priming for word retrieval.

A closer look at individuals indicated that priming is extremely variable both within and between individuals. Moreover, none of the cognitive skills tested appeared to explain this variability. Given the lack of individual reliability of the priming effect, it is likely that no cognitive skill would be predictive. This calls into doubt the reliability of generalising from the group results to the individual (Stolz, Besner & Carr, 2005). Establishing the reliability of an effect at the level of the individual is particularly important if, for example, one wishes to determine whether priming is unimpaired in individuals with language and/or cognitive impairments. This study has highlighted this issue and further research should investigate the reliability of priming within individuals further using a larger set of items to improve statistical power.

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Appendix A

Contrast Vectors for Overall Effects of Priming

Note: Min1=1st presentation of Minutes items; Min2 = 2nd presentation of Minutes; Min3 = 3rd presentation; Min4 = 4th presentation. Day1 = 1st presentation of Day items; Day2 = 2nd presentation of Day; Day3 = 3rd presentation; Week1 = 1st presentation of Week items; Week2 = 2nd presentation of Week; CS1a =control items from 1st half of Session 1; CS1b = Control items from 2nd half of Session 1; CS2 = Controls from Session 2; CS3 = Controls from Session 3.

Main Priming Effect:	**Min1**	**Min2**	**Day1**	**Day2**	**Week1**	**Week2**	**CS1a**	**CS1b**	**CS2**	**CS3**	**Min3**	**Min4**	**Day3**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Minutes priming (controlling for practice effect)	-1	1	0	0	0	0	1	-1	0	0	0	0	0
Day priming (controlling for practice effect)	0	0	-1	1	1	0	0	0	-1	0	0	0	0
Week priming (controlling for practice effect)	0	0	1	0	-1	1	0	0	0	-1	0	0	0
Comparisons of Priming Conditions:	**Min1**	**Min2**	**Day1**	**Day2**	**Week1**	**Week2**	**CS1a**	**CS1b**	**CS2**	**CS3**	**Min3**	**Min4**	**Day3**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Min v Day priming (controlling for session effects)	-1	1	1	-1	-1	0	1	-1	1	0	0	0	0
min v week (controlling for session effects)	-1	1	-1	0	1	-1	1	-1	0	1	0	0	0
day v week (controlling for session effects)	1	0	-1	1	1	-1	-0.5	-0.5	-1	1	0	0	0

Appendix B

Contrast Vectors for Priming * Age Group Interaction

Note: M1=1st presentation of Minutes items; M2 = 2nd presentation of Minutes; M3 = 3rd presentation; M4 = 4th presentation. D1 = 1st presentation of Day items; D2 = 2nd presentation of Day; D3 = 3rd presentation; W1 = 1st presentation of Week items; W2 = 2nd presentation of Week; CS1a =control items from 1st half of Session 1; CS1b= Control items from 2nd half of Session 1; CS2 = Controls from Session 2; CS3 = Controls from Session 3.

	M1	M2	D1	D2	W1	W2	CS 1a	CS 1b	CS 2	CS 3	M3	M4	D3	M1	M2	D1	D2	W1	W2	CS 1a	CS 1b	CS 2	CS 3	M3	M4	D3
Contrast	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Minutes Priming	-1	1	0	0	0	0	1	-1	0	0	0	0	0	1	-1	0	0	0	0	-1	1	0	0	0	0	0
Day Priming	0	0	-1	1	1	0	0	0	-1	0	0	0	0	0	0	1	-1	-1	0	0	0	1	0	0	0	0
Week Priming	0	0	1	0	-1	1	0	0	0	-1	0	0	0	0	0	-1	0	1	-1	0	0	0	1	0	0	0

	M1	M2	D1	D2	W1	W2	CS 1a	CS 1b	CS 2	CS 3	M3	M4	D3	M1	M2	D1	D2	W1	W2	CS 1a	CS 1b	CS 2	CS 3	M3	M4	D3
Contrast	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Min vs Day	-1	1	1	-1	-1	0	1	-1	1	0	0	0	0	1	-1	-1	1	1	0	-1	1	-1	0	0	0	0
Min vs Week	-1	1	-1	0	1	-1	1	-1	0	1	0	0	0	1	-1	1	0	-1	1	-1	1	0	-1	0	0	0
Day vs Week	1	0	-1	1	1	-1	-0.5	-0.5	-1	1	0	0	0	-1	0	1	-1	-1	1	0.5	0.5	1	-1	0	0	0

Appendix C

Model output from Analysis of Variance for Raw priming and Proportional priming.

Note: Raw priming measures: ((2nd presentation-1st presentation) - (Control 2-Control 1)). The proportional priming: ((2nd presentation – 1st presentation)/(Control 2 - Control 1))

Dependent Variable: Raw Priming (ms)					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	117877.999a	5	23575.6	3.287	0.008
Intercept	627201.479	1	627201.479	87.454	0
Group	430.538	1	430.538	0.06	0.807
Delay	103595.905	2	51797.952	7.222	**0.001**
Group * Delay	13851.557	2	6925.778	0.966	0.383
Error	989702.347	138	7171.756		
Total	1734781.83	144			
Corrected Total	1107580.35	143			
a R Squared = .106 (Adjusted R Squared = .074)					

Dependent Variable: Proportional Priming					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.186a	5	0.037	4.253	0.001
Intercept	0.883	1	0.883	101.239	0
Group	0.018	1	0.018	2.083	0.151
Delay	0.157	2	0.079	8.998	**0**
Group * Delay	0.01	2	0.005	0.592	0.555
Error	1.204	138	0.009		
Total	2.273	144			
Corrected Total	1.39	143			
a R Squared = .134 (Adjusted R Squared = .102)					

Appendix D

Model output from individual analyses using Linear Mixed Effects Modelling.

Note: Significant results are bolded with an asterisk. Results approaching significance (p <.1) are in italics

Participant	Minutes				Day				Week			
Older Adults	Estimate	Std. Error	z value	p value (Holm)	Estimate	Std. Error	z value	p value (Holm)	Estimate	Std. Error	z value	p value (Holm)
O1	-.035	.046	-.746	.455	-.044	.034	-1.274	.405	*-.076*	*.034*	*-2.213*	*.081*
O2	-.045	.038	-1.191	.473	-.042	.030	-1.413	.473	-.001	.030	-.027	.978
O3	-.045	.038	-1.191	.473	-.042	.030	-1.413	.473	-.001	.030	-.027	.978
O4	-.050	.027	-1.848	.194	-003	.021	-.160	.873	-.019	.021	-.883	.754
O5	-.002	.042	-.045	1	.007	.032	.231	1	-.018	.033	-.553	1
O6	-.078	.042	-1.874	.183	-.035	.032	-.073	.567	.006	.032	.189	.850
O7	***-.183***	***.060***	***-3.070***	***.006****	-.003	.046	-.056	1	.008	.048	.162	1
O8	-.031	.037	-.849	.792	-.043	.029	-1.504	.397	.016	.029	.571	.792
O9	-.074	.040	-1.825	.204	-.029	.031	-.919	.716	-.029	.031	-.918	.716
O10	.023	.039	.579	.563	***-.076***	***.031***	***-2.430***	***.045****	*.062*	*.031*	*1.984*	*.095*
O11	-.074	.042	.043	.248	-.036	.032	-1.131	.516	-.027	.032	-.831	.516
O12	-.097	.048	-2.017	.131	-.041	.038	-1.077	.563	.019	.038	.511	.609
O13	-.056	.039	-1.452	.293	***-.084***	***.030***	***-2.772***	***.017****	.030	.030	.983	.326
O14	-.036	.031	-1.148	.752	.005	.025	.208	1	.006	.025	.260	1
O15	-.038	.031	1.255	.629	-.005	.024	-.226	1	-.013	.024	-.545	1
O16	.013	.039	.354	1	-.007	.031	-.246	1	-.012	.030	-.388	1
O17	-.015	.047	-.325	.987	-.025	.036	-.685	.987	-.064	.036	-1.769	.231
O18	-.004	.040	-.106	.916	-.037	.031	-1.185	.708	-.029	.030	-.955	.708
O19	-.036	.039	-.912	.616	-.040	.032	-1.266	.616	.040	.032	1.245	.616
O20	-.068	.033	-2.032	.126	.000	.026	.004	1	-.007	.026	-.285	1
O21	-.027	.042	-.641	1	.041	.033	1.219	.668	-.017	.034	-.494	1
O22	-.038	.040	-.943	.691	-.024	.032	-.748	.691	-.054	.032	-1.666	.286
O23	-.038	.036	-1.064	.861	.003	.029	.118	1	.011	.028	.383	1
O24	-.000	.031	-.001	1	-.039	.025	-1.595	.332	.015	.024	.613	1

Young Adults	Estimate	Std. Error	z value	p value (Holm)	Estimate	Std. Error	z value	p value (Holm)	Estimate	Std. Error	z value	p value (Holm)
Y1	-.028	.054	-.514	.902	-.042	.043	-.962	.902	-.045	.044	-1.035	.902
Y2	-.032	.045	-.699	.958	-.033	.036	-.902	.958	-.036	.036	-.996	.958
Y3	-.046	.035	-1.315	.566	-.015	.027	-.549	1	.010	.027	.358	1
Y4	-.048	.034	-1.416	.313	-.026	.027	-.972	.331	-.053	.027	-1.958	.151
Y5	-.027	.032	-.865	.647	.024	.025	.988	.647	-.046	.025	-1.856	.190
Y6	-.063	.041	-1.535	.374	-.034	.032	-1.062	.577	.027	.032	.842	.577
Y7	-.021	.037	-.549	1	-.032	.030	-1.049	.882	.016	.030	.523	1
Y8	-.024	.044	-.560	1	-.054	.034	-1.586	.338	-.022	.034	-.630	1
Y9	-.031	.050	-.605	1	-.031	.040	-.779	1	-.005	.040	-.129	1
Y10	-.076	.039	-1.935	.106	*-.067*	*.030*	*-2.217*	*.080*	-.020	.030	-.656	.512
Y11	.007	.033	.217	1	-.031	.025	-1.234	.651	.010	.025	.401	1
Y12	*-.068*	*.031*	*-2.204*	*.083*	-.019	.024	-.791	.453	-.029	.024	-1.209	.453
Y13	.048	.046	1.051	.586	-.004	.036	-.116	.907	-.072	.036	-1.985	.141
Y14	-.083	.046	-1.798	.138	*-.083*	*.036*	*-2.328*	*.060*	-.065	.035	-1.818	.138
Y15	-.063	.036	-1.747	.161	-.062	.029	-2.135	.098	-.018	.029	-.619	.536
Y16	-.073	.036	-2.014	.132	-.023	.028	-.797	.798	-.024	.028	-.843	.798
Y17	-.036	.046	-.793	.855	***-.108***	***.035***	***-3.073***	***.006****	.018	.035	.508	.855
Y18	***-.118***	***.045***	***-2.617***	***.027****	-.020	.035	-.577	1	.003	.035	.089	1
Y19	-.039	.023	-1.720	.256	-.031	.018	-1.713	.256	-.015	.018	-.853	.393
Y20	-.073	.037	-1.996	.138	-.041	.028	-1.431	.305	-.024	.029	-.842	.400
Y21	-.085	.036	-2.346	.057	-.027	.028	-.969	.665	.007	.028	.260	.795
Y22	-.040	.030	-1.362	.520	-.028	.024	-1.180	.520	-.006	.024	-.265	.791
Y23	*-.101*	*.046*	*-2.219*	*.060*	-.086	.037	-2.329	.060	.035	.036	.975	.330
Y24	-.057	.039	-1.462	.335	-.047	.029	-1.590	.335	.006	.029	.205	.837

Appendix E

Correlation results

Note: To correct for multiple comparisons, p-value must be below .005 to be considered significant

		Minutes	Day	Week	Age	Episodic Memory	Digit Span	Attention	WCST standard score	Fluency Category	Fluency Letter
Day	Pearson's r	-.122	—								
	p-value	.571	—								
Week	Pearson's r	.013	-.452	—							
	p-value	.952	.027	—							
Age	Pearson's r	.117	.101	-.442	—						
	p-value	.585	.637	.031	—						
Episodic Memory	Pearson's r	-.101	-.013	.145	-.235	—					
	p-value	.638	.952	.5	.269	—					
Digit Span	Pearson's r	-.364	.113	-.011	.156	.149	—				
	p-value	.08	.598	.961	.466	.489	—				
Attention	Pearson's r	-.036	-.008	-.276	-.055	.135	.192	—			
	p-value	.868	.971	.191	.8	.53	.369	—			
WCST standard score	Pearson's r	.164	-.189	-.201	.121	.178	-.009	.409	—		
	p-value	.444	.376	.346	.574	.405	.965	.047	—		
Fluency Category	Pearson's r	.344	.001	-.015	-.073	.236	-.02	.313	.13	—	
	p-value	.1	.998	.946	.734	.268	.927	.137	.544	—	
Fluency Letter	Pearson's r	.01	-.095	-.206	.081	-.485	-.369	.248	.157	.137	—
	p-value	.964	.659	.334	.705	.016	.076	.243	.465	.522	—

Chapter 5 (Paper 4)

Priming for Success: Repetition Priming in Aphasia

Abstract

Repetition priming has been proposed as a mechanism underpinning treatment-related improvements in word retrieval in aphasia: having named an item previously increases the accessibility of that item and the likelihood of success on subsequent naming attempts. However, there has been little research examining the extent and time course of repetition priming in people with aphasia. This study is the first to concentrate on repetition priming in people with aphasia with no treatment or feedback.

Nine individuals with aphasia named pictures over three sessions. Target items were repeated for naming (using different exemplars) at three target delays: either separated by minutes within session, one day later, or one week later. Items repeated at the shorter lags were also presented again in any subsequent sessions to examine if there was any additional benefit from extra repetitions.

At the group level, one repetition within a session significantly reduced naming latencies of the second attempt. However, this was not significant at the longer delays of one day or one week. No significant effects were found on accuracy. Similarly, no significant effects of additional repetitions were found. At the individual level, large variation both between and within individuals was apparent. Examining language and other cognitive skills did not reveal any specific skills associated with priming.

In conclusion, people with aphasia showed repetition priming effects on picture naming latency in the short term and this was not associated with any of the other cognitive skills tested.

Introduction

It is well established that treatment can improve word retrieval in people with aphasia (Wisenburn & Mahoney, 2009). However, no single treatment has been found to be effective for every individual with aphasia (Nickels 2002b). This is not surprising given the varied nature of language deficits between individuals. However, it is also the case that no strong connection has been reliably identified between the specific nature of an individual's word production deficit and the type of treatment that is effective. For example, individuals with deficits in lexical-semantic processing have also been found to benefit from phonologically-focused treatments and conversely, individuals with post semantic deficits have been found to benefit from treatments focused on semantic processing (e.g., Lorenz & Ziegler, 2009).

Repetition priming has been proposed as a possible mechanism underlying treatment-related improvements in word retrieval for people with aphasia (e.g., Nickels, 2002a). In unimpaired speakers, repetition priming in this context refers to faster picture naming when presented with targets for a second time (e.g., Wheeldon & Monsell, 1992). This effect has been well established in the short term, with unimpaired speakers responding faster to pictures repeated within the same session (e.g., Creet et al., 2018b,c; Durso and Johnson, 1979; Wheeldon & Monsell, 1992) and longer term (e.g., 1-6 weeks, Mitchell and Brown (1988), 48 weeks, Cave (1997)).

It is possible that those individuals with aphasia who fail to respond to treatment are those who have impaired repetition priming. Surprisingly, there is little research examining repetition priming in people with aphasia. Soni, Lambon Ralph and Woollams (2012) examined very short-term priming in five people with aphasia (0, 1, or 7 intervening items). They found improved accuracy at all three time delays but latency improvements were no longer present with 7 intervening items before the second naming attempt. Critically, however, in this experiment, if the person with aphasia failed to produce the correct response, the target was provided for them to repeat aloud. Hence this experiment is not strictly equivalent to investigations of repetition priming in unimpaired speakers. Of two people with aphasia, Heath et al. (2015) found that one participant showed no improvement in accuracy from either multiple attempts at naming (with no feedback) two to four days earlier or a single attempt earlier in the same session. However, supporting the hypothesis that people with aphasia may vary in their response to priming, the other participant showed significantly improved accuracy from multiple attempts at naming days earlier compared to unfacilitated (and previously unnamed) controls (latency was not examined). In contrast, no significant effects were found for this participant on accuracy of a single previous naming attempt within the testing session. This would seem to suggest that, for this participant, a number of repetition priming events (naming attempts) were required to achieve changes in accuracy. However, as the long-term priming condition also allowed time for consolidation (including sleep: Dumay & Gaskell, 2007) it is also possible that this could have contributed to the difference between the conditions.

Nevertheless, given that people with aphasia often have lower accuracy and slower response times than unimpaired speakers, it seems plausible that some individuals may require more than one repetition in order to show priming effects. In a study of three people with aphasia, Wingfield, Brownell and Hoyte (2006) investigated object naming over five presentations within a single session. All participants had high accuracy above 92% on the first trial, and were given the correct target name on incorrect trials. No significant effects were found on accuracy. Two of the three participants showed no improvement in latency over the five attempts, in fact they both became slower across the session. One participant however, became progressively faster with each naming opportunity. This suggests that at least some people with aphasia may benefit from cumulative effects of priming and this is explored in the current study.

Similar benefits from repeated naming attempts have been reported in other people with aphasia (e.g., over seven days, Nickels, 2002a; in sentence completion within a session, Hatfield, Howard, Barber, Jones & Morton, 1977). In a study of 23 individuals with aphasia who underwent a treatment programme (Morris, Howard & Buerk, 2014), we (Creet, Morris, Howard & Nickels, 2018) found improvements for items named (but not treated) in four participants even when naming attempts were at six week intervals. There was evidence suggesting that, in order to show a positive change in accuracy over time, a level of variability in naming accuracy was required and unimpaired performance on the Modified Wisconsin Card Sorting Test (M-WCST: Schretlen, 2010) was also associated with improvement. We hypothesised that the executive skills that the M-WCST is thought to require could be important in order that only correct responses are primed (as opposed to priming incorrect responses; see also Fillingham, Sage & Lambon Ralph, 2005a; 2005b; 2006). However, not all people who displayed these skills/behaviours, showed improvements, so this cannot be the full picture. Perhaps for some individuals, priming had decayed such that the six week gap between naming attempts was too long to maintain any benefit.

Given the paucity of data in the literature, the aim of this study was to explore the nature of repetition priming in people with aphasia. Three different time delays between repetitions were examined to look at the time course of priming and explore the speed of decay (Analysis 1: Priming effects). Some items were repeated more than once to determine whether there was any cumulative improvement in accuracy or latency from additional naming attempts (Analysis 2: Effects of cumulative presentations). The priming results were then compared to older adults without a language impairment (Creet et al. 2018c) to examine any differences in the amount or time course of priming (Analysis 3: Comparison with Older adults without aphasia). Finally, priming patterns of individual participants were examined separately given that people with aphasia display large variation in language and other cognitive impairments (Analysis 4: Individual effects of priming). This analysis also attempted to uncover any specific language or other cognitive skills necessary for priming of word retrieval to occur.

Method

Participants

Participants were nine native speakers of British English (3 male; 6 female) who had previously been diagnosed with aphasia by a speech and language therapist, following a cerebro-vascular accident (stroke) and had vision and hearing sufficient to participate in the assessments. They were recruited through the North East Trust for Aphasia and were aged between 50 and 87 years (mean: 69; SD: 10). No neuroimaging data was available for these participants. One additional participant was recruited but excluded from analysis, due to extremely low accuracy (1% correct).

Background Assessment

All participants also completed background language and other (non-language) cognitive tests (see Table 1) in order to be able to examine whether specific cognitive processes were associated with repetition priming. These tests were conducted spread over a number of sessions, following the experimental task. Many participants also required a fourth session to complete the cognitive and language assessments. See Appendix A for a description of the tests conducted.

Table 1
Participants' demographics and scores on language and other cognitive tests. Scores outside of normal limits (i.e., compared to unimpaired speakers) are bolded.

Participant			PA	PB	PC	PD	PE	PF	PG	PH	PI
Age			69	74	67	64	65	50	87	77	68
Sex			Male	Female	Male	Male	Female	Female	Female	Female	Female
Years Education			12	16	15	11	13	13	11	14	14
Time Post Stroke (years)			3	4	4	2	11	5	16	9	16
Test Scores	Max Score	Cut-off									
PALPA subtest 50: written synonym judgement	60	52[1]	57	60	60	49	NA	55	54	40	53
PALPA subtest 49: auditory synonym judgement	60	-	49	34	59	32	46	47	56	40	55
CAT subtest 2: Semantic Memory	10	9	10	10	10	10	10	10	10	**5**	10
CAT Repetition subtest 12: Words	32	30	**13**	**12**	32	**25**	**14**	**11**	32	**13**	32
CAT Repetition subtest 14: Non-words	10	6	**2**	**0**	6	8	**4**	**4**	8	6	10
CAT subtest 17: Object Naming	48	44	**32**	**38**	45	**14**	**26**	**12**	**21**	**3**	**42**
Monitoring (of above items)	24	-	23	23	24	17	21	15	16	17	24
Written Naming	24	-	6	23	23	6	4	18	12	1	21
Camden Face Memory	25	18	25	25	24	21	24	24	**14**	21	23
Wechsler Forwards & Backwards Digit Span	24	5	**3**	**3**	16	**4**	**4**	6	8	**0**	7
PALPA subtest 13: matching span	7	-	7	4	7	7	4	7	5	4	5
BCoS Sustained Attention	54		41	53	54	43	NA[2]	50	NA[2]	NA[2]	54
M-WCST standard score		70	129	126	111	87	**65**	79	93	**58**	102
Error Proportion (current study)			.66	.34	.06	.87	.59	.65	.41	.90	.11

Note: Cut-off = Minimum score to be considered within normal limits. PALPA = Psycholinguistic Assessments of Language Processing in Aphasia (Kay, Lesser & Coltheart, 1996). CAT = Comprehensive Aphasia Test (Swinburn, Porter & Howard, 2004). BCoS = Birmingham Cognitive Screen (Humphreys, Bickerton, Samson & Riddoch, 2012). Forwards and Backwards Digit Span (Wechsler, 1987). The Camden Short Memory Test for Faces (Warrington, 1996). M-WCST = The Modified Wisconsin Card Sorting Test (Schretlen, 2010); Error proportion is the percentage of errors made on all unprimed items in the current study. [1] Normative data taken from Nickels & Cole-Virtue, 2004 [2]These three participants could not follow the instructions on the BCoS Sustained Attention task and therefore the test was terminated early.

Materials

The target pictures used in this experiment were 768 coloured photographs, depicting 192 nouns with four different exemplars of each, all with previous name agreement of 90% or higher (see Creet et al., 2018b). Different exemplars were used to minimise any priming effects due to faster picture identification (see Creet et al., 2018b for discussion).

The target items were divided into six sets of 32 items matched on name agreement, (log) spoken word frequency (van Heuven, Mandera, Keuleers & Brysbaert, 2014), length in phonemes and syllables (Davis, 2005), age of acquisition (Kuperman, Stadthagen-Gonzalez & Brysbaert, 2012), concreteness (Brysbaert, Warriner, & Kuperman, 2014) and visual complexity (as indicated by file size, Székely, & Bates, 2000). These sets were then assigned to conditions, counterbalancing such that every set appeared in every condition an equal number of times and that each exemplar appeared in a different order in each version. Each participant completed a separate version. An additional 114 pictures were used as (novel) fillers (spread across sessions).

Procedure

Participants were tested individually at Newcastle University. All sessions were run using the experimental software DMDX (Forster & Forster, 2003). The experiment began with written instructions displayed on the screen explaining that participants would see pictures of single items, which they were asked to name aloud with one word as quickly as possible. They were informed that some items might appear multiple times so not to hesitate to repeat any names again. These instructions were also paraphrased verbally by the experimenter. A practice trial preceded the experiment with five practice items. The main experiment then began with five filler items at the start. Each trial began with a fixation cross for 250ms, followed by the picture, which remained until the participant made their response and the trial was manually terminated by the experimenter, or for a maximum of 5000ms. A blank screen then appeared until the experimenter manually moved on to the next trial. Each session consisted of 165 items (target and fillers) and lasted approximately 20-40 minutes depending on speed of naming and the number of breaks taken throughout.

Participants were tested across three sessions on days 1, 2 and 8. This allowed manipulation of three time lags for repetition priming (see Figure 1): a lag of several minutes between first and second presentation of a target within Session 1 (Minutes), a lag of one day by Session 2 (Day), and a lag of one week by Session 3 (Week). In addition, items were re-presented in any subsequent sessions to examine the effects of multiple repetitions on priming. In each session, a set of novel items (control sets, 1, 2, 3), previously unseen in the experiment, was presented to provide control for effects of session on response latency.

Condition	**Session 1** (Day 1)	**Session 2** (Day 2)	**Session 3** (Day 8)	**Delay**	**Number of Presentations**
Minutes	 Test 1  Test 2	 Test 3	 Test 4	**Minutes** (& 1 day, & 1 week)	4
Day	 Test 1	 Test 2	 Test 3	**1 day** (& 1 week)	3
Week	 Test 1		Test 2 	**1 week**	2
Control				not repeated	1

Figure 1. A visual representation of the experimental conditions.

On Day One, all three target delay conditions were presented for the first time (Minutes, Day, Week) as well as a set of control items (Controls Session 1) which were not repeated in any other sessions. The Minutes items were also presented for a second time in this session, separated by at least 50 items from the first presentation. On Day Two, the items in the Minutes delay condition were presented for the third time, the Day items were presented for the second time, and Controls Session 2 for the first time. In the third session on Day 8, the Minutes delay items were presented for the fourth time, the Day items for the third time, the Week items for the second time, and Controls Session 3 for the first time.

Response scoring

Responses were scored correct when the target item was successfully named. Close alternative names (e.g., *spectacles* for *glasses*) were also scored as correct, if the participant used the same alternative name on additional presentations (alternative depictions) of that item. Only participants' first response attempt was scored, with any later self-corrections marked incorrect (e.g., for the target *duck* the response *bird...duck* or *bir...duck* were both scored as incorrect). However, if a single phoneme was uttered before a full attempt at an response, this was ignored (e.g., *s...duck* was considered correct).

Data analysis

Response recordings were opened in CheckVocal (Protopapas, 2007), coded as correct or incorrect, and response latencies adjusted as necessary such that they coincided with the onset of the response. Response times were measured from when the correct (or alternative) response was initiated (e.g., *s...duck* was measured from the start of *duck*). These data were then analysed in R-Studio (R Core Team, 2013), using mixed effects modelling with lme4 package (Bates et al., 2015).

For accuracy data, a logistic mixed effects model was fitted using the entire data set of 3456 trials with Condition (the time delay and presentation number, e.g., first presentation of day condition) as the fixed effect. The random effects structure included random intercepts for the Participants and Targets: (Accuracy ~ Condition + (1 | Participant) + (1 | Target)).

Contrast coding was then used for all analyses to compare the conditions of interest. Priming was evaluated by comparing the difference between first and second presentations of items, minus any difference between the two sets of control (unrepeated) stimuli from the same two sessions to control for effects of session.

For analyses of the reaction time data, only correct responses were analysed, removing 1704 trials from the analysis (49%). A further 9 trials were removed due to delayed answering (e.g., distracted by previous trial or coughing). To improve normality of the model residuals, a logarithmic transformation was used. A linear mixed effects model was constructed, the dependent variable was log RT, with Condition as the fixed effect. The random effects structure included random intercepts for the Targets and random intercepts and slopes for Condition by Participant: (LogRT ~ Condition + (1 + Condition | Participant) + (1 | Target)).

Results

Unsurprisingly, there was considerable between participant variation in both accuracy and latency. Looking at all unprimed items, error proportion ranged from .06 to .90 with an average error rate of .51. Average response latency for unprimed items was 1567ms ranging from 1070ms to 2239ms. The group results for both latency and accuracy data for each condition are reported in Table 3.

Table 3

Mean and standard deviations of error proportion and latency (in milliseconds).

Condition	Presentation 1 (Unprimed)	Presentation 2 (Primed)	Presentation 3 (Primed)	Presentation 4 (Primed)
Error Proportion	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Minutes	.451 (.498)	.476 (.500)	.431 (.496)	.431(.496)
Day	.514 (.501)	.507 (.501)	.483 (.501)	
Week	.538 (.499)	.521 (.500)		
Control S1	.486 (.501)			
Control S2	.549 (.498)			
Control S3	.519 (.501)			
Latency (ms)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Minutes	1568 (806)	1461 (915)	1378 (689)	1414 (731)
Day	1519 (743)	1398 (678)	1491 (728)	
Week	1523 (819)	1522 (803)		
Control S1	1577 (803)			
Control S2	1601 (874)			
Control S3	1587 (876)			

Analysis 1: Priming Effects

The primary research question was whether individuals with aphasia showed repetition priming: whether they improved their naming performance (accuracy and/or latency) on the second presentation while controlling for any variation between sessions (e.g., due to practice/tiredness).

Using these comparisons between presentations (controlling for session effects), participants on average improved their naming accuracy for repeated items by 12% (SD=.11) within the same session, 1% (SD=.13) one day later, and 3% (SD=.14) one week later. Looking at the naming latencies, participants were on average 461ms (SD=1087) faster for the repeated items within minutes in the same session; 199ms (SD=460) faster when repeated a day later, and 69ms (SD = 499) faster when repeated a week later.

The priming effect was analysed using contrast coding to take both item and session effects into account. The contrasts examined the difference in latency/accuracy from the first to the second presentation, compared to the difference in the relevant controls across sessions. For example, to examine the priming effect over one day, the first presentation of the Day set was coded as -1, and the second presentation was coded as 1 to provide the difference between these two sets (the raw priming effect). The effect of session was controlled by coding Control Session 1 as 1 and Control Session 2 as -1, and all other cells set to zero (see matrix in Appendix B). For the Minutes comparison, the control was for change across the course of the session and was achieved by splitting Control Session 1 in half (first half and second half) for contrasts. Note that due to the fact that Control Session 1 was split into two halves (Control Session 1A, Control Session 1B) to analyse within session effects in Session 1, for analyses across other sessions, we replaced the Control 1 with another set of items which were also presented for the first time in Session 1. For the Day analyses, this was Week 1; and for the Week analyses this was Day 1.

Whether there was a significant difference in the amount of priming at different delays was examined by contrasting the priming at each delay (controlled for session effects). For example, to examine if there was any difference between Minutes and Day priming, Minutes 1 was coded as -1, Minutes 2 as 1, Control Session 1 as 1, Control Session 1B as -1. Day 1 was coded as 1, Day 2 as -1; Week 1 coded as -1 (to act as session 1 control), and Control Session 2 as 1.

No significant priming effects were found on accuracy (see Table 4).

For the latency data, although on average all three delays resulted in numerically faster naming, this was only significant for the shortest delay of Minutes (see Table 4). There were no significant differences in the amount of priming for latency between any of the conditions. Figure 2 displays the average latencies for the first and second presentations of the priming conditions (Minutes, Day and Week) as well as the relevant control items from the same two sessions.

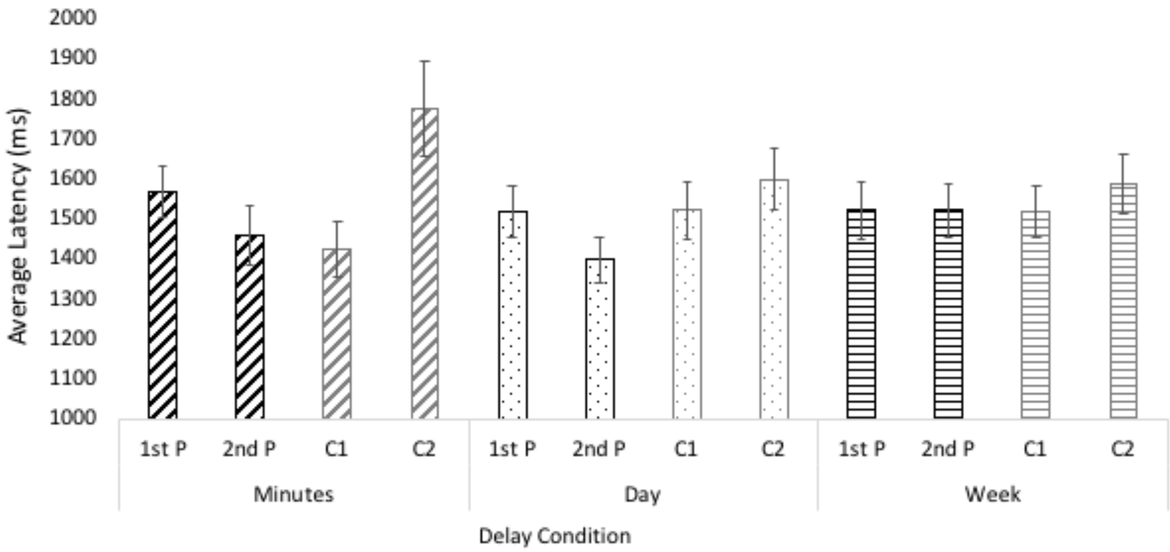

Figure 2. Average latency in milliseconds and standard error bars for the first presentation of items (unprimed), the second presentation of items (primed) compared to the control* items from the same two sessions for each delay condition. 1st P = first presentation; 2nd P = second presentation; C1 = Control for 1st presentation; C2 = Control for 2nd presentation. *Note that first control for Day is the first presentation of Week, and the first control for Week is the first presentation of Day.

Table 4
Priming in each delay condition, controlling for session effects, and comparisons of these priming effects (all p values corrected using Holm-Bonferroni corrections)

Contrasts	Estimate	Std. Error	z value	p value (Holm)
Accuracy Analyses				
Overall Priming Effect:				
Minutes Priming	.443	.401	1.105	.808
Day Priming	.140	.319	.440	1
Week Priming	.209	.318	.657	1
Comparison between delay conditions:				
Minutes vs Day Priming	.303	.513	.591	1
Minutes vs Week Priming	.235	.512	.458	1
Day vs Week Priming	.329	.450	.730	1
Response Latency Analyses				
Overall Priming Effect:				
Minutes Priming	-.125	.049	-2.584	**.029***
Day Priming	-.044	.033	-1.329	.368
Week Priming	-.032	.040	-.790	.430
Comparison between delay conditions:				
Minutes vs Day Priming	-.081	.068	-1.187	.471
Minutes vs Week Priming	-.094	.046	-2.047	.122
Day vs Week Priming	-.041	.048	-.846	.471

Discussion of Analysis 1. At the group level, individuals with aphasia did not show significant improvement in picture naming accuracy on the second presentation whether this was within a session, after one day or one week. However, participants named items significantly faster on the second presentation when this was with a delay of minutes, within the same session. Although naming items for the second time one day or one week later was numerically faster, this was not significant. However, there were no significant differences in the amount of priming between the different delay conditions. These contrasting results are possibly due to the large variation in response times and relatively small amounts of data for some individuals (due to low naming accuracy). Potential individual variation and any individual factors such as language or other cognitive capabilities will be further explored in the individual analyses below.

Analysis 2: Effects of Cumulative Presentation

Given that individuals with aphasia tend to be slower and less accurate than unimpaired speakers, it is possible that people with aphasia receive greater benefit from additional repetitions. Therefore, we examined whether there was any additional benefit from repeating items more than once. Do individuals show greater priming, or priming that is more resistant to decay, having previously named an item twice (or three times) rather than just once?

To address this question, we compared any difference in the amount of priming of items across conditions appearing in the same session and that had been presented differing number of times). For example, in Session 2, we examined whether there was a significant difference between the amount of priming from the second presentation of Day items, compared to the third presentation of Minutes items (see Figure 3). The amount of priming of each condition was calculated as the difference between the first presentation and the repeated presentation. Hence, the contrast matrix was constructed with Minutes 1 coded as -1, Minutes 3 coded as 1; and Day 1 coded as 1, Day 2 coded as -1. Since we are looking across the same two sessions in both analyses, the control items are the same and therefore cancel each other out in the contrasts.

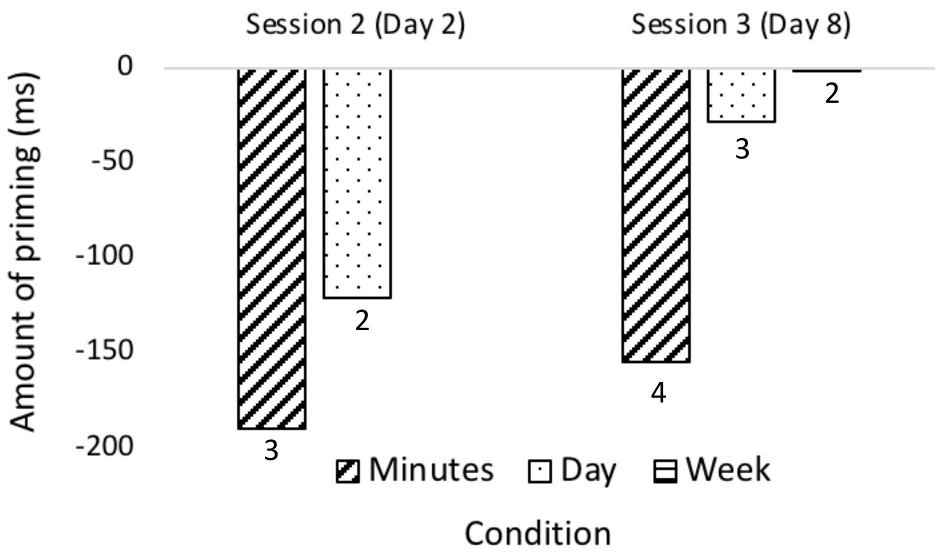

Figure 3. Comparison of the amount of priming for repeated items in Sessions 2 and 3. The presentation number (2nd to 4th presentation of the target for naming) is indicated under the bars

There were no significant effects of additional repetitions on response latency (see Table 5). There was however, a significant difference in accuracy when comparing the second presentation of Week items and the fourth presentation of Minutes items in Session 3: the Minutes items showed significantly greater priming compared to the Week items. We then looked to see if there was significant priming of accuracy on these items. This was achieved by comparing the accuracy of the first and fourth presentation of Minutes items, while controlling for the change in accuracy across the control items in the first and third sessions. There was a significant difference in the change in accuracy (i.e., priming) between the repeated items and the control items ($z = -1.774$, $p = .038$, 1-tailed).

Table 5

Comparisons of the amount of priming for different number of presentations (all p values corrected using Holm-Bonferroni corrections)

Contrasts	Estimate	Std. Error	z value	p value (Holm)
Response Time Analyses				
Session 2: Minutes3 vs Day2 Priming	-.030	.038	-.798	1
Session 3: Minutes4 vs Day3 Priming	-.034	.037	-.909	1
Session 3: Minutes4 vs Week2 Priming	-.031	.044	-.689	1
Session 3: Day3 vs Week2 Priming	-.004	.038	-.106	1
Accuracy Analyses				
Session 2: Minutes3 vs Day2 Priming	.129	.314	.411	1
Session 3: Minutes4 vs Day3 Priming	-.047	.314	-.151	1
Session 3: Minutes4 vs Week2 Priming	1.121	.326	3.453	**.002**
Session 3: Day3 vs Week2 Priming	.072	.314	.229	1

Discussion of Analysis 2. Although in Analysis 1, we found clear effects of priming on latency within a session, in this analysis there was no increase in priming from additional repetitions: Increasing the number of naming opportunities did not significantly improve naming speed. However, we did not examine the effects of multiple repetitions within a session. Given the short duration of significant priming effects (no longer significant a day later), it is possible that if the third (or fourth) presentations were at closer intervals, additional priming effects may have eventuated.

In contrast to latency, there was a significant effect of number of repetitions on accuracy - but this was only after four presentations: Items that were named for the fourth time after naming twice within session, and once a day later, showed significantly higher accuracy compared to items only named for the second time after a week. Moreover, these items were the only items to show significant priming. This indicates that perhaps for many people with aphasia, multiple naming attempts are required to significantly improve items. The varied nature of naming accuracy in people with aphasia may mean that with one repetition, while some items have improved, just as many may have become worse.

Therefore, multiple attempts are required to successfully produce and then prime items to improve subsequent performance.

These results provide insight into the effects extra practice can have on naming for people with aphasia. A future study could explore multiple repetitions at consistent time delays to see if either closer intervals or more repetitions would lead to significant priming of latency.

Analysis 3: Comparison with Older Adults without aphasia

In order to determine whether people with aphasia show 'intact' priming, it is necessary to compare them to adults without aphasia of similar age. We had previously conducted the same experiment with twenty-four older adult participants without aphasia, aged between 58 and 85 (mean = 71, SD = 6) (see Creet et al, 2018c). Participant groups did not differ significantly in age ($t(31) = 0.75$ $p = 0.458$ two tailed). These older adult participants were significantly faster at naming primed items (whilst controlling for session effects) at both the Minutes (108ms priming) and Day (47ms priming) delays, whereas priming at one Week (37ms) was not significant. Nevertheless, there were no significant differences between the amount of priming in the delay conditions. There were no significant effects of repetition on accuracy for this older adult group, potentially due to very low error rates (.03). As the group of people with aphasia also showed no significant effects on accuracy, we did not compare the groups on this measure, but instead focused on latency.

When comparing two groups of participants who differ in baseline latency, it is unclear whether the appropriate metric is absolute change in response latency (e.g., 20msec; e.g., Mitchell et al., 1990) or proportional change (e.g., 5% change; e.g., Wiggs et al., 2006). Therefore, we also calculated new proportional priming measures when comparing the groups using the formula ((primed latency – baseline latency)/baseline latency) while also controlling for session effects ((2^{nd} presentation-1^{st} presentation)/1^{st} presentation) - ((Control 2- Control

1)/Control 1). We then compared the groups using analyses of variance[4] with the two different priming measures: proportional priming and raw difference in milliseconds (see Table 6).

Table 6
Mean priming values for people with aphasia and older adults without language impairment. Priming is reported in both raw latency difference and proportional difference.

Unprimed Latency (ms)		**Raw Priming (ms)**			**Proportional Priming**		
		Min	**Day**	**Week**	**Min**	**Day**	**Week**
People with aphasia							
Mean	1567	-461	-199	-69	-.317	-.131	-.045
SD	818	1087	460	499	.670	.227	.320
Older adults							
Mean	959	-108	-47	-37	-.113	-.050	-.039
SD	109	114	91	95	.112	.095	.101
Unprimed Error Rate		**Raw Priming Accuracy**			**Proportional Priming**		
		Min	**Day**	**Week**	**Min**	**Day**	**Week**
People with aphasia							
Mean	.510	.118	.014	.031	.120	.186	.173
SD	.500	.110	.132	.144	.240	.502	.560
Older adults							
Mean	.031	.021	.017	-.012	.021	.016	-.006
SD	.173	.048	.071	.053	.050	.056	.060

In the raw latency priming analysis, there was a significant main effect of Group: F (1, 93) = 15.60, p < .001 and Delay: F (2, 93) = 6.52, p < .001. People with aphasia showed significantly greater priming, and there was less priming at longer delays. There was also a significant interaction between Group and Delay: F (2, 93) = 4.21, p = .002. Examining the difference between the groups within each delay condition, there were no significant differences in the extent of raw priming between the people with aphasia and the older adult controls, although there was a trend for greater priming at the shortest delay (Minutes delay:

[4] Due to the complexity of the contrasts required across conditions in the Linear Mixed Effects Modelling used in this study, it was not possible to submit proportional values to the model, since they already contained contrasts across conditions.

t(8.07) = 1.91 p = .092, two tailed; Day: t(8.23) = 1.43 p = .189, two-tailed or Week t(8.22) = 0.68 p = .513, two-tailed; NB, as the variances between the groups were unequal, Welsh's t-tests were performed).

The same pattern emerged for the proportional latency priming analysis. There was a significant main effect of Group: F (1, 93) = 14.76, p < .001, and Delay: F (2, 93) = 7.21, p < .001, as well as a significant interaction: F (2, 93) = 3.44, p = .001. Comparing within each delay, again there were no significant differences between the groups (Minutes delay: t(8.17) = 1.85 p = .101, two-tailed; Day: t(9.08) = 1.20 p = .259, two-tailed or Week: t(8.60) = 1.16 p = .277, two-tailed).

Discussion of Analysis 3. Regardless of the priming measure (proportional or raw), the same pattern emerged: A main effect of both Group and Delay, as well as a significant interaction between the two. This pattern seemed to be driven by a steeper slope in the reduction of priming for people with aphasia (who only showed significant priming at minutes) than the older adults (who showed significant priming at both minutes and day (Creet et al., 2018c)). However, further comparison revealed that there were no significant differences between the groups for any of the delay conditions. This was somewhat surprising given the large differences in average priming values (especially at the shorter intervals). It is possible that this was due to a large variation in priming between individuals, as was found with the older adult participants (Creet et al., 2018c). This will be explored in the next set of analyses.

Analysis 4: Individual effects of priming

It is well known that people with aphasia present with varied language and cognitive deficits, and the standard deviations on the priming effects suggested that this was also the case here and the group effects masked huge differences in priming. Looking at individuals' priming of latency, it is clear that there is not only a lot of variation between individuals, but also within individuals from session to session (see Figure 4 and Table 7).

To examine whether each individual showed significant priming on accuracy, a logistic mixed effects model was fitted using all trials for each participant separately. Condition (the time delay and presentation number, e.g., first presentation of day condition) was the fixed effect, with Targets as a random intercept: (Accuracy ~ Condition + (1|Target). No individual showed significant effects of priming on accuracy (see Appendix C for the full output).

For the latency data, a linear mixed effect model was constructed in R for each participant separately. The dependent variable was log RT, with condition as the fixed effect and Targets entered as random effects (Log RT ~ Condition + (1 |Target)). There were few significant effects on latency: Participant A showed significant priming for Minutes and Week; and Participant E for Day (see Appendix B). Although, Participant H appears to show a large effect in the minutes condition, this was not significant, most likely due to the small number of correct items (n=49, (13%)) giving reduced power.

We further examined whether variation in the extent of individual priming effects was associated with any cognitive or language skills: No measure significantly correlated with priming at any time point (see Appendix D).

Table 7

Naming and priming patterns for each individual with aphasia. Older adult control mean results also reported.

Note: Mean latency and error proportions are for unprimed items (first presentation) only. ***Bold Italics*** represent significant priming effects in the linear mixed effect analysis.

Ppt	**Mean latency (ms) (SD)**	**Mean Error Proportion**	**Latency**						**Accuracy**					
			Raw Priming (ms)			**Proportional Priming**			**Raw Priming**			**Proportional Priming**		
			Min	**Day**	**Week**	**Min**	**Day**	**Week**	**Min**	**Day**	**Week**	**Min**	**Day**	**Week**
PA	1900 (1049)	.66	***-2582****	253	***-1207****	-1.920	.147	-.734	-.063	.031	.250	-.154	.385	.598
PB	1665 (852)	.34	-358	-229	-132	-.237	-.138	-.077	.188	.219	-.219	.236	.590	.069
PC	1458 (480)	.06	-349	-128	-1	-.217	-.089	-.001	.063	.000	.125	.063	.032	.163
PD	1448 (444)	.87	-519	-73	-453	-.455	-.082	-.496	.125	-.156	.063	.500	.143	1.714
PE	2239 (959)	.59	341	***-1264****	339	.197	-.636	.166	.313	-.125	.125	.664	-.234	.127
PF	1621 (726)	.65	-431	-65	-247	-.256	-.043	-.200	.094	-.063	-.125	.313	.284	-.083
PG	1666 (875)	.41	-342	-22	560	-.275	-.006	.310	.219	-.063	.094	.230	-.056	.180
PH	1872 (994)	.90	-2759	-765	-87	-1.371	-.362	-.281	.031	.188	-.063	.300	1.467	.000
PI	1070 (572)	.11	-232	-120	-147	-.226	-.113	-.137	.094	.094	.031	.106	.069	.034
Mean	1567	.51	-461	-199	-69	-.317	-.131	-.045	.118	.014	.031	.200	.186	.173
SD	818	.50	1087	460	499	.670	.227	.320	.110	.132	.144	.240	.502	.560
Older Adult Controls														
Mean	959	.03	-108	-47	-37	-.113	-.050	-.039	.021	.017	-.012	.021	.016	-.006
SD	109	.02	114	91	95	.112	.095	.101	.048	.071	.053	.050	.056	.060

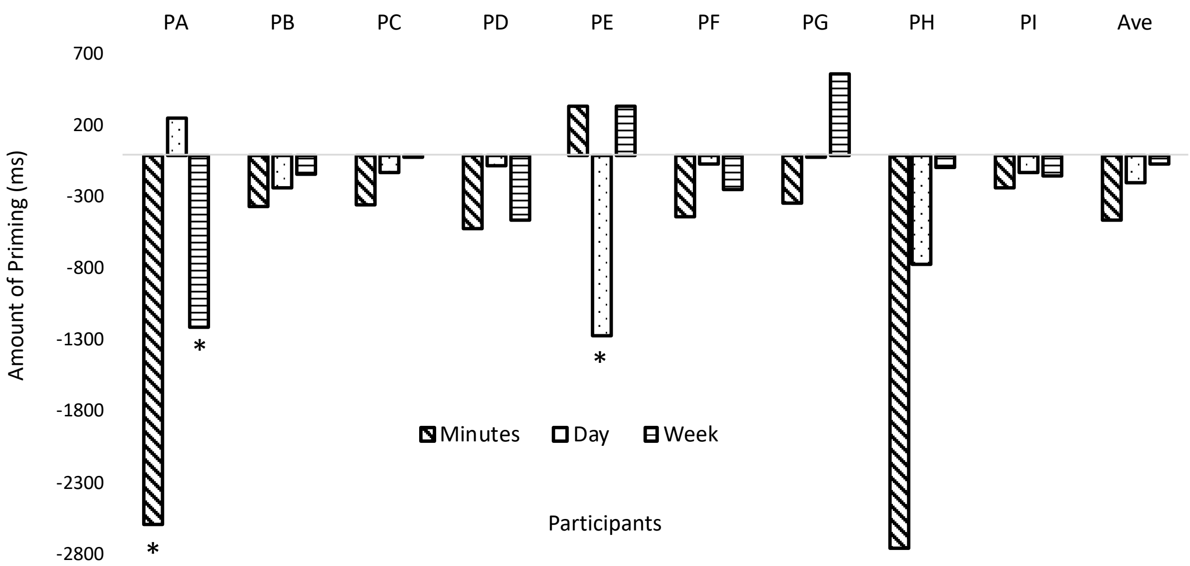

Figure 4. The mean amount of priming in milliseconds (controlling for session effects) for each delay condition. Presented for each participant with aphasia and as a group average. Negative values indicate faster responses at the second presentation (i.e., priming).

Discussion of Analysis 4. By looking at the individuals separately, it was apparent that there was large variation in priming effects both between individuals and within individuals between delay conditions. Perhaps between participant variation is be expected in people with aphasia, given how heterogeneous the disorder is. But the large within subject variation is more surprising. For example, Participant E shows no priming in the shortest condition, but showed significant priming a day later. Several participants showed the reverse pattern and did not present with priming in the Day delay condition but did in the Minutes and Week conditions. However, this variability was consistent with individual analyses of older controls (Creet et al., 2018c), suggesting that priming may not be as robust at the individual level as group results may suggest (also see: Fisher, Medaglia & Jeronimus, 2018; Stoltz, Besner & Carr, 2005). Moreover, no language or other cognitive skills seemed to explain this variation - we were not able to identify a specific cognitive skill that was a prerequisite for successful priming.

General Discussion

The aim of this study was to examine the time course of repetition priming in people with aphasia. At the group level, we found no significant priming of accuracy from a single previous naming attempt. However, people with aphasia were faster to name primed targets compared to control items, even when different pictorial representations of the same target were presented at each naming attempt. However, there was only significant priming of latency at the shortest time delay - a lag of minutes within the same session. Although, one day and one week later, naming was on average faster when a target was re-presented for naming, this difference was not significant. Compared to unimpaired controls of a similar age, participants with aphasia showed greater priming overall and particularly at the shortest lag.

The presence of significant (larger than usual) within session priming of latency, but the absence of significant priming at one day and one week, suggests a very rapid decay of the initial priming. This rapid decay does not seem consistent with studies that have shown (for some individuals) benefits from previous repeated attempts at naming at even six week intervals (Creet et al., 2018a) or many treatment studies which only have therapy once a week and yet show improvement (e.g., Best, Grassly, Greenwood, Herbert, Hickin & Howard, 2011; Hickin, Best, Herbert, Howard & Osborne, 2002).

Previous research has found that for some people with aphasia, attempting to name an item can improve accuracy of later naming without any treatment or feedback (Creet et al., 2018a; Nickels, 2002a). The current study did not find any priming effects on accuracy from a single repetition. However, three previous naming attempts (2 within a session and 1 a day later), resulted in significant improvement in naming latency a week later. Given that accuracy in people with aphasia often varies from session to session, it may take more attempts for successful naming to occur and which then leads to priming of correct target words. When the correct word is produced, the activation and selection of the target word results in a lowering of its selection threshold, or strengthening of the connections from previous levels of processing, and therefore it is retrieved faster on subsequent attempts (Howard et al., 2006). It was previously hypothesised that perhaps even when target production is unsuccessful activation of the semantics and phonology of the target may be sufficient to prime the target (Creet et al, 2018a; Nickels, 2002a), with this priming slowly accumulating until there is sufficient additional activation to allow the target to be successfully produced. The results from the current study suggest that a single unsuccessful attempt would not produce sufficient priming for the item to be successfully named. It remains unclear whether in order to be primed, the item must be successfully produced. However, it seems likely that, for error-prone stimuli, in order to either successfully produce the item or for priming to accumulate sufficiently, several naming attempts are required.

It is possible that if participants were given the correct answer to produce following an error, that these results may have been different - this may prime items in the same way as correctly naming an item spontaneously. This would be consistent with treatments that show significant benefit for items repeated without naming attempts; for example, Repetition in the Presence of a Picture, whereby the therapist provides the target name of the picture for the patient to repeat multiple times (e.g., Croot et al., 2015; Mason et al., 2011; Morris et al., 2015). However, it has been suggested that successful retrieval can lead to longer term success compared to repetition of target alone (Middleton, Schwartz, Rawson & Garvey, 2015). In a repetition priming study in which the correct target was provided to repeat following incorrect naming attempts, Soni et al., (2012), found that five people with aphasia showed priming of accuracy and latency from a single repetition. However, these effects were extremely short lived. At the second attempt, participants were both significantly faster and more accurate with 0 intervening items, with 1 intervening item they were still significantly faster however their accuracy was only close to significant ($p=.052$), and neither measure was significant at 7 intervening items. This indicates a very steep decay with only one repetition. In the current study, people with aphasia showed significant priming effects on latency with approximately 50 intervening items with no correction provided.

However, as we found for older adults without aphasia (Creet et al., 2018c), the data in our study suggest a great deal of variability within and between individuals. Repetition priming does not appear to be as robust within individuals as group results suggest. In order to explore individual variation more thoroughly, larger sets of data are required to provide sufficient power to examine individual patterns.

To summarise, significant priming of picture naming latency was found that lasted several minutes within a session for people with aphasia even using different depictions of items. Longer delays did not result in significant priming of latency, even with one or two additional repetitions. The only significant effect on naming accuracy was found after four presentations, indicating that repeated practice is required when no treatment or feedback is provided. Similar to unimpaired speakers (Creet et al., 2018c), there was a lot of individual variation. However, individual language or other cognitive skills were not able to account for this. This implies that repetition priming could be a distinct dissociable mechanism that does not rely on other cognitive processes.

Overall this has important implications for understanding treatment mechanisms and providing treatment protocols. It appears that for some individuals with aphasia, one repeated attempt in the short term can increase speed of naming without any treatment or feedback. To gain effects on accuracy with no support in naming, more repetitions are required. Future studies could extend the study of cumulative effects with more repetitions at different lags and explore improvements in accuracy at the individual level with a larger data sample.

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Appendix A

Cognitive test descriptions

1. Conceptual Semantic Processing:
   - Semantic Memory Test (Comprehensive Aphasia Test (CAT subtest 2; Swinburn, Porter & Howard, 2004), requires participants to point to the one of four pictures that is most associated to a central picture e.g., *watch* goes with *wrist*. This aims to look at nonlinguistic semantic knowledge.
2. Comprehension:
   - Written and Spoken Synonym Judgements (Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay, Lesser & Coltheart, 1996) subtest numbers 50 and 49 respectively): Participants are presented (either verbally or written) with two words and must indicate whether they are synonyms or not, with half the items being of high imageability (e.g. 'ocean-sea' vs 'ocean-donation') and the remainder of low imageability (e.g, agreement-consent' vs 'agreement – threat').
3. Spoken Output:
   - Spoken Repetition of words and nonwords (CAT; Swinburn et al., 2004) subtest numbers 12 and 14. Repetition of 16 words differing in imageability, frequency and length. Repetition of 5 nonwords varying from 1-2 syllables. 2 points are awarded for correct and rapid response. 1 point is awarded for 5 second delay or any corrections.
   - Spoken picture Naming (CAT subtest 17; Swinburn et al., 2004). Participants are required to name 24 pictures of objects with names varying in frequency and of 1 to 3 syllables in length. 2 points are awarded for correct and rapid response. 1 point is awarded for 5 second delay or any corrections.
4. Written Naming:
   - Participants were instructed to write down the name of the items that they named in the CAT object picture naming task (subtest 17) immediately after naming each of them.

5. Other Cognitive Assessments:

Memory:

- Digit Matching Span (PALPA subtest 13; Kay et al., 1996) measures short term memory. Participants listen to two strings of digits and must indicate whether the numbers are repeated in the identical order or not, with two lists at each string length from two to seven digits.
- The Wechsler Forwards and Backwards Digit Span (Wechsler, 1987) is another measure of short-term memory. Participants repeat a string of numbers aloud of string length from three up to a possible eight. Two strings are presented at each length. The task is discontinued when both attempts at a string-length are incorrect. The task is then repeated with the participants required to recall the numbers in backwards order, for string lengths from two to seven digits. This task has a maximum score of 24 (1 point per correct list).
- The Camden Short Memory Test for Faces (Warrington, 1996) examines episodic memory. Participants are shown 24 photos of men's faces to judge whether the person looks pleasant or not. Immediately following this, they are re-presented with each face next to a new face. Participants must indicate which face they have seen before.

Attention:

- The Birmingham Cognitive Screen (BCoS) sustained attention task (Humphreys, Bickerton, Samson & Riddoch, 2012) requires participants to listen multiple strings of six different words and tap on the table when predetermined target words occur ('hello' 'please' and 'no') and ignore distractor words ('goodbye' 'thanks' and 'yes'). This task aims to assess sustained attention, selective attention, working memory and inhibition of the related distractor words.

Executive Function:

- The Modified Wisconsin Card Sorting Test (M-WCST; Schretlen, 2010) is a card sorting task which requires participants to place cards in one of four piles based on a rule (either colour, number or shape) that is not revealed to the participant. Once the participant successfully follows the rule for six consecutive turns, the rule changes and the new rule must be determined. The task is designed to assess executive functioning including rule discovery and following, task switching, working memory and inhibition (of previous rules).

Monitoring:

- Following each item in the CAT picture naming task (subtest 17), participants were required to indicate whether they thought they had correctly named the picture. The aim of this task was to determine whether there was a relationship between correct monitoring and repetition priming.

Appendix B

Contrast Vectors for Overall Effects of Priming.

Note: Min1=1st presentation of Minutes items; Min2 = 2nd presentation of Minutes; Min3 = 3rd presentation; Min4 = 4th presentation. Day1 = 1st presentation of Day items; Day2 = 2nd presentation of Day; Day3 = 3rd presentation; Week1 = 1st presentation of Week items; Week2 = 2nd presentation of Week; CS1a =control items from 1st half of Session 1; CS1b = Control items from 2nd half of Session 1; CS2 = Controls from Session 2; CS3 = Controls from Session 3.

Main Priming Effect:	**Min1**	**Min2**	**Day1**	**Day2**	**Week1**	**Week2**	**CS1a**	**CS1b**	**CS2**	**CS3**	**Min3**	**Min4**	**Day3**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Minutes priming (controlling for practice effect)	-1	1	0	0	0	0	1	-1	0	0	0	0	0
Day priming (controlling for practice effect)	0	0	-1	1	1	0	0	0	-1	0	0	0	0
Week priming (controlling for practice effect)	0	0	1	0	-1	1	0	0	0	-1	0	0	0
Comparisons of Priming Conditions:	**Min1**	**Min2**	**Day1**	**Day2**	**Week1**	**Week2**	**CS1a**	**CS1b**	**CS2**	**CS3**	**Min3**	**Min4**	**Day3**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Min v Day priming (controlling for session effects)	-1	1	1	-1	-1	0	1	-1	1	0	0	0	0
min v week (controlling for session effects)	-1	1	-1	0	1	-1	1	-1	0	1	0	0	0
day v week (controlling for session effects)	1	0	-1	1	1	-1	-0.5	-0.5	-1	1	0	0	0

Appendix C

Model output from individual analyses using Linear Mixed Effects Modelling.

Note: Significant results are bolded with an asterisk. Results approaching significance (p <.1) are in italics

Participant	Minutes				Day				Week			
Latency	Estimate	Std. Error	z value	p value (Holm)	Estimate	Std. Error	z value	p value (Holm)	Estimate	Std. Error	z value	p value (Holm)
PA	-.478	.127	-3.777	**<.001***	.069	.100	.691	.490	-.274	.097	-2.826	**.009***
PB	-.127	.093	-1.364	.518	-.051	.073	-.700	.968	.024	.074	.320	.968
PC	-.105	.055	-1.922	.164	-.062	.045	-1.375	.338	.019	.045	.419	.675
PD	-.199	.157	-1.265	.618	-.065	.205	-.314	.909	-.183	.245	-.748	.909
PE	.084	.094	.897	.678	-.233	.085	-2.736	**.019***	.079	.082	.956	.678
PF	-.160	.129	-1.241	.644	-.016	.101	-.158	.875	-.088	.108	-.815	.831
PG	-.129	.092	-1.400	.485	.013	.082	.159	.874	.096	.078	1.230	.485
PH	-.378	.176	-2.143	*.097*	-.137	.166	-.823	.821	-.016	.138	-.119	.905
PI	-.045	.063	-.717	.947	-.055	.049	-1.117	.792	-.015	.049	-.298	.947
Accuracy												
PA	-.393	1.247	-.315	1	.284	.993	.286	1	1.611	.994	1.621	.315
PB	1.121	1.339	.838	.483	1.345	.986	1.365	.483	-1.374	.980	-1.402	.483
PC	32.830	1.678e7	.000	1	.012	16.530	.001	1	17.500	475.100	.037	1
PD	.969	2.877	.337	1	-3.726	3.562	-1.046	.887	1.922	3.627	.530	1
PE	2.300	1.409	1.633	.307	-.831	1.079	-.770	.794	.910	1.075	.847	.794
PF	.922	1.468	.628	1	-.434	1.146	-.379	1	-.977	1.170	-.834	1
PG	2.090	1.597	1.308	.572	-.462	1.177	-.392	1	.617	1.184	.521	1
PH	.075	3.522	.021	.983	3.331	3.163	1.053	.590	-3.878	3.004	-1.291	.590
PI	3.717	4.366	.851	1	1.643	3.083	.533	1	1.409	3.294	.428	1

Appendix D

Correlations between priming values and cognitive tests

P-value must be .003 to survive correction for multiple comparisons

		Minutes	Day	Week	Written judgement	Auditory judgement	Semantic Memory	Rep words	Rep nonwords	Object Naming	Monitoring	Written Naming	Memory test for faces	Digit Span	matching span	BCoS Attention
Day	r	-0.172	—													
Week	r	0.6	-0.518	—												
Written judgement	r	0.514	0.694	-0.083	—											
Auditory judgement	r	0.157	0.203	0.247	0.346	—										
Semantic Memory	r	0.674	0.405	-0.049	0.83	0.252	—									
Rep words	r	0.379	0.314	0.356	0.132	0.572	0.291	—								
Rep nonwords	r	0.189	0.064	0.329	-0.43	0.366	-0.079	0.787	—							
Object Naming	r	0.368	0.255	-0.056	0.777	0.455	0.59	0.403	-0.105	—						
Monitoring	r	0.079	0.054	-0.247	0.543	0.267	0.303	0.169	-0.213	**0.902***	—					
Written Naming	r	0.507	0.424	0.139	0.757	0.339	0.5	0.347	-0.045	0.679	0.416	—				
Memory test for faces	r	-0.05	-0.09	-0.54	0.355	-0.193	0.144	-0.506	-0.571	0.386	0.584	0.235	—			
Digit Span	r	0.477	0.295	0.29	0.566	0.72	0.466	0.706	0.312	0.573	0.296	0.627	-0.063	—		
matching span	r	-0.078	0.682	-0.558	0.329	0.2	0.41	0.19	0.093	0.058	-0.071	0.147	0.16	0.437	—	
Attention	r	0.756	-0.789	0.884	0.44	0.389	NaN	0.36	0.139	0.555	0.351	**0.984***	0.215	0.551	-0.551	—
WCST standard score	r	-0.03	0.707	-0.475	0.844	0.157	0.546	0.162	-0.356	0.746	0.646	0.559	0.295	0.29	0.318	-0.02

Chapter 6

General Discussion

This thesis aimed to investigate factors affecting improvement in word retrieval for people with aphasia. Specifically, by examining repetition priming effects in both unimpaired speakers and people with aphasia, at both the group and individual level, this thesis hoped to help understand a possible mechanism underpinning treatment effectiveness. It also aimed to inform our understanding of repetition priming of word retrieval more broadly, exploring for example the time course, cumulative effects, impact of visual factors and age-related effects on priming.

Firstly, this chapter will summarise the main findings of each of the four experimental papers. Then these findings, their limitations, and what each contributes to our understanding of word retrieval will be integrated to draw out implications for our understanding of naming improvement in people with aphasia.

Chapter 2 (Paper 1) explored improvements in accuracy for people with aphasia as a result of repeated attempts at naming. Despite these attempts being at six-week intervals, four individuals showed a significant improvement over time. Somewhat unexpectedly, two other individuals with aphasia showed significant decline in accuracy across the seven naming attempts. The conditions which appeared to lead to these changes will be discussed below.

The improvement from repeated attempts at naming was hypothesised to be driven by the same mechanism underlying repetition priming. Given that this has also been suggested to be the mechanism underlying treatment improvements, it is surprising how little is known about repetition priming effects in people with aphasia. The remaining three experimental chapters of this thesis focused on learning more about repetition priming effects in both unimpaired speakers and people with aphasia.

The main themes explored were:

- the time course of repetition priming when visual effects were minimised by using changed exemplars
- cumulative effects of priming
- age-related effects of priming
- the reliability of priming effects at the individual level
- and repetition priming effects in people with aphasia

Chapter 3 (Paper 2) was the first study to look at the time course of repetition priming using different exemplars of items, and did so in young adults. Experiment 1 looked at the time course from a matter of minutes within a session, up to one week between presentations. This study found significant repetition effects priming on latency in all three time delays (Minutes, Day and Week). The magnitude of priming was also significantly less at the one week delay compared to the earlier delays of minutes and one day. There were no significant cumulative effects of repetition on priming; participants did not show greater priming with additional naming trials.

Experiment 2 extended the time period, looking at the time course of priming from one to four weeks. Again, all delays resulted in significant priming of picture naming latency (1-Week, 2-Weeks, 4-Weeks). However, these longer-term delays revealed a stable magnitude of priming, with no significant differences between the delays. Again, there were no significant effects of additional repetitions.

Overall, this study found that even with changed exemplars, repetition priming lasts at least four weeks in unimpaired young adult speakers, indicating that the mechanism of priming is long lasting. The priming is largest at shorter delays but appears to level off at longer delay periods. These data reveal that priming does not increase from additional repetitions, suggesting that the mechanism underlying priming is not additive, or that for this population, the maximum benefit has been reached at the first repetition. However, given that the additional repetitions also included effects of lag (as they were not at the same delay as the first repetition), these findings must be interpreted cautiously.

Chapter 4 (Paper 3) explored repetition priming in older adults and examined whether there were any age differences between older and younger adults. The older adults displayed significant priming both within a single session and one day later. In contrast to the young adults, priming was no longer evident at a lag of one week. However, there was no evidence of a difference in priming across the delay conditions, nor any interaction between age and priming. Therefore, there was little evidence that there are age related differences in the priming of word retrieval.

Unlike the findings in this thesis, previous studies have found significant priming beyond one week for older adults (e.g., Mitchell, Brown& Murphy, 1990; Wiggs, Weisberg & Martin, 2006). Several reasons for this difference were proposed in Chapter 4. These differences will be discussed below in the statistical analysis section.

This chapter also explored repetition priming effects in unimpaired speakers at an individual level for the first time. The results were rather striking in terms of the large variability both within and between individuals. This will be discussed in more detail below.

Chapter 5 (Paper 4) investigates the time course of repetition priming in people with aphasia. This was the first study to look at repetition priming with only a single repetition, with no treatment or feedback, and using different exemplars of items. As a group, there was significant priming of picture naming latency at the shortest delay of a matter of minutes: People with aphasia were able to retrieve the word faster when repeated (with a different exemplar) approximately 50 items later. The two longer delays of one day and one week did not result in significant priming effects on latency. Even one day later, this latency advantage appeared to have decayed. Even when previously primed items of Minutes, were named for the third time one day later, there was no priming of latency compared to the first presentation of these items (controlling for session). However, despite the apparent evidence of decay of priming, there was not a statistically significant difference in priming effects between the three delay conditions. Again, this is likely due to variability in priming, which will be discussed further below.

As for the unimpaired speakers, there was no significant priming of accuracy from one repetition at any of the delays. However, the individuals with aphasia did show significant priming of accuracy after four presentations. This suggests that when accuracy is low and no correction is provided, repeat practice is required in order for naming improvements to occur.

Key Themes Addressed

Visual effects:

Repetition priming has been thought to be underpinned by improvements in word retrieval. However, most priming studies use identical pictures at both time points, which confounds the effects with faster visual processing and/or picture recognition. An important aspect of the three repetition priming papers of this thesis was the use of different exemplars of items at each repetition. Beyond a lag of minutes (Wheeldon & Monsell, 1992) up to two days (Cave & Squire, 1992), previous studies had all used identical prime and target, making it difficult to conclude that priming of word retrieval really does last long term. In a picture identification study using incomplete picture fragments, Mitchell (2006) found that people were significantly more accurate at identifying pictures which they had seen seventeen years previously, compared to new pictures. Given this evidence that visual effects can be extremely long lasting, this seemed to cast some doubt on whether very long-term repetition priming studies (e.g., Cave, 1997: 48-week delay) have actually tapped into priming of word retrieval as opposed to priming of picture identification. By using different exemplars, this thesis has demonstrated that it is the case that priming of word retrieval can last up to four weeks and appears to be stable from one to four weeks. However, the amount of priming was less than previously reported for similar lags using identical pictures (e.g., Durso & Johnson, 1979; Mitchell & Brown, 1988). Consequently, further research is required to determine how long this priming would remain stable for, and whether it would last 48 weeks, when visual effects are minimised.

Nevertheless, in this thesis, the use of different exemplars cannot completely exclude visual effects; some visual similarity is inevitable between exemplars of the same target. Future studies of unimpaired speakers could explore long term priming using a different modality of priming, such as a naming following a written definition (cf Wheeldon & Monsell, 1992). However, this methodology was not appropriate for this thesis which had as a priority to investigate repetition priming in people with aphasia. In order to investigate word retrieval in people with aphasia, it is imperative to not add an additional language task (such as naming to definition) which may affect results. Given that individuals with aphasia can have reading or auditory comprehension difficulties, picture naming is the most appropriate task to assess word retrieval.

Another possibility for future research is to examine the effect of the amount of visual similarity between pictures on the extent of priming in order to further tease out the impact visual effects have on priming. For example, comparing the amount of priming received from either: identical pictures of cupboards, similar looking cupboards, or very different looking cupboards (and also the effect of orientation). The other area to explore is whether manipulating visual similarity through the use of different subordinates may have had an impact on priming. For example, dog: could have two pictures of the same Labrador dog for the prime and target, two pictures of different Labradors; or one Labrador and one Poodle. This thesis did not control for this in the stimuli, however, given evidence that subordinate names are activated and can potentially compete during word production (Jescheniak et al., 2017), this is another possible influence on naming times. Consequently, it is important to determine whether the potential co-activation of alternative names may have affected priming.

Cumulative effects of priming:

The results of cumulative priming in this thesis were mixed. In Paper 1, four people with aphasia benefited from cumulative effects of priming on accuracy, even at six-week intervals, and in Paper 4, as a group, people with aphasia showed cumulative priming effects on accuracy only on the fourth presentation. However, Papers 2 and 3 did not find any cumulative effects of priming on latency or accuracy for young or older unimpaired speakers. We will return to the effects of accuracy in the section below, and here focus on the (lack of) effects on latency.

It is relatively well established that repetition priming effects on latency are large on the first presentation, and substantially reduced on subsequent presentations (e.g., Kurtz, Schriefers, Mädebach & Jescheniak, 2018; perhaps due to a ceiling on how much faster lexical retrieval can become). In combination with the relatively long-lasting effects of priming, it is therefore perhaps not unsurprising that cumulative effects are small. However, Wheeldon and Monsell (1992) proposed that the mechanism underpinning repetition priming was the same mechanism responsible for frequency effects. In other words, the accessibility of high frequency words is due to the cumulative priming of these words in everyday language compared to less frequently used words. However, the pattern found in this thesis of no cumulative effects of priming but long-term priming effects four weeks after the initial prime seems to present a challenge to theories which have priming and frequency as the same mechanism.

Age Related Effects:

As mentioned in Paper 3, given that there is evidence that older adults have weakened connections to phonological forms (Shafto & Tyler, 2014), it might be expected that they may receive a greater benefit from repetition priming in comparison to young adults. Conversely, since some cognitive processes have been found to decline with age (e.g., short-term memory, reasoning; Myerson, Hale, Wagstaff, Poon & Smith, 1990; Salthouse, 1996), it is possible that some cognitive skills required for priming may not be functioning well. This could result in less priming. Either way, one might expect to see some differences. Consequently, Paper 3 examined whether there were any age-related effects on priming, comparing younger and older adults: There were no significant differences between the groups. This supports previous studies of both Mitchell et al. (1990) and Wingfield, Brownell and Hoyte (2006), who found no age-related differences in the amount of priming. However, Wiggs et al. (2006) found a significant interaction between age and delay, with older adults showing a decay in the magnitude of priming at an earlier stage compared to young adults. This was the same pattern observed in the group average priming values in Paper 3. However, this difference was not significant, perhaps due to the large individual variation.

However, this paper has shown that whilst priming of word retrieval is extremely variable at the individual level, it does not appear to consistently vary between age groups. Moreover, in this thesis there were no correlations with priming effects and age within the older adult group either, which suggests that differences in ages of participants across studies with older adults are unlikely to account for the (slight) differences in findings.

Individual effects:

Paper 3 was the first study to examine individual effects of repetition priming in unimpaired speakers. These results showed a wide variability both within and between individuals for both young and older adults.

While further research with a larger set of items, with the power to determine the reliability of priming within individuals, is needed for confirmation, this study provides the first indication that priming may not be as robust at an individual level as previous results have suggested. This highlights the often neglected issue of the potential dangers of generalising group results to the individual (Fisher, Medaglia & Jeronimus, 2018). This supports previous work examining the individual (un)reliability of semantic priming of lexical decision, in which large variation was found (Stoltz, Besner & Carr, 2005). The authors attributed this variability to uncoordinated and noisy processes underlying semantic memory. However, it contrasts with their follow up study, which found reliable repetition priming of lexical decision within an individual, although the extent of priming did vary across participants (Waechter, Stoltz & Besner, 2010). Clearly this is a very different task, but future research should examine reliability of these effects both within an individual (from item to item or session to session) and across individuals by using suitably powered studies. Given how much of psycholinguistic experimentation and theory relies on priming – should this not be found to be a consistent cognitive phenomenon, the consequences are potentially immense. Moreover, attempting to establish the reliability of priming within individuals is especially important in order to determine whether priming is intact in individuals with aphasia if this is a prerequisite for some kinds of treatment to be effective.

Changes in Accuracy:

Paper 1 focused on improvements in accuracy. This study found that people with aphasia who were more variable in their naming of items in the first two sessions (i.e., named the item correct once, and incorrect the other time or vice versa), were more likely to show a change in accuracy overall across the experiment. This variability in accuracy is a common feature of aphasia: individuals may be consistent overall in the number of items they produce correctly from one session to the next but different items are named correctly (Howard, Patterson, Franklin, Morton, & Orchard-Lisle, 1984). Paper 1 supports the hypothesis that this variability, where the correct word is sometimes produced, leads to increased availability of the target words after repeated attempted naming (Nickels, 2002): when the correct target is selected, it is hypothesised the connections between the semantic and phonological forms are strengthened.

Importantly, this was the first study to show that this change in accuracy can go in either direction. Whilst it does appear that variability in naming can lead to the correct response being strengthened over time, worryingly, it can also lead to incorrect responses being primed. This means that for some people with aphasia, independent practice of naming can lead to improvement, while for others, this could lead to their naming of certain items becoming even worse – practice may make permanent as opposed to perfect. Clearly this is a critical piece of information for treatment of anomia given that treatment may involve multiple presentations of control (untreated) items or may include some conditions without feedback.

In the priming studies, no changes in accuracy were found for the unimpaired participants, which is, perhaps, to be expected given their relatively accurate naming performance. For the people with aphasia, Paper 4 did not find significant change in accuracy across sessions - it was not until the fourth presentation of an item that there was significant priming. These results suggest that for some individuals with aphasia, to improve accuracy of naming (with no support in naming), more attempts at naming may be required. The only effects of accuracy in this study was with four presentations (the maximum number of repetitions).

Together, Papers 2 and 4, have found evidence that longer lags between naming attempts, when presented multiple times, can produce priming effects for some individuals. Future studies could further explore these cumulative effects on accuracy with more items to improve statistical power and explore the number of repetitions of items to see how many are required and the effect of time lags between presentations and whether this varies across individuals.

Whether attempting to name an item could lead to strengthening of (correct or incorrect) connections, or whether the item must be successfully (or incorrectly) produced for this strengthening to occur is not clear. Middleton, Schwartz, Rawson and Garvey (2015) found that successful retrieval led to greater benefit compared to failed attempts, despite the correct target being provided after both instances. This could be a fruitful area for future research – using item analysis to determine whether the items that show improvement are those that are successfully produced in an earlier session.

Cognitive Predictors:

Both Paper 3 (older adults) and Paper 4 (people with aphasia) revealed wide variation both within and between participants in the extent of priming in each delay condition. In both studies, the question was asked whether this variability might be explained by differences in other aspects of cognitive processing that may be required for priming to occur. There have been studies that have found a relationship with cognition and general naming in aphasia. For example, Kuzmina and Weekes (2017) tested Russian speakers with aphasia on four different cognitive control tasks. They found that picture naming was correlated with the Birmingham Cognitive Screen's (BCoS) subtest on Sustained Attention (measuring verbal cognitive control, particularly, verbal selective attention) for fluent and non-fluent people with aphasia, and with the Stroop task (measuring verbal cognitive control) for the fluent group only. In another study, Baldo et al. (2005) found a significant correlation between the Wisconsin Card Sorting Task (WCST) and language measures. They looked at various possible measures of the WCST, for example, the percent correct, percentage of perseverative errors, conceptual understanding as well as different language measures such as naming, fluency, repetition and comprehension. While they did not look at overall standardised WCST scores, they did find a significant correlation with the percent correct in the task and naming, Aphasia Quotient and comprehension. No significant correlations were found with fluency or repetition. However, in our studies 3 and 4, we did not find that the extent of repetition priming was correlated with any language or cognitive skills, for latency, or accuracy either at the first repetition or, for people with aphasia, at the fourth presentation (where significant priming of accuracy was evident).

While this could indicate that priming is a distinct cognitive mechanism, this finding may be also a direct result of the unreliability of the measurement of the priming effect and/or the cognitive skills. In addition, it is possible that the cognitive assessments did not tap those specific skills required, future studies could also attempt to measure a wider range of cognitive skills with a broader range of tests. Ideally a large cognitive test battery would be used which better isolated specific cognitive skills (e.g., different aspects of memory, sustained attention and attentional control, inhibition control, relational reasoning).

Paper 1 did, however, find an association between improvement with repeated naming attempts and the Modified Wisconsin Card Sorting Task, which is supposed to tap into executive functioning skills (including rule discovery and rule following, rule switching, working memory and inhibition of previous rules). No other cognitive or language tasks were associated with naming accuracy. However, this association was only found in the overall group but was not consistent in the subset of individuals who showed significant change (in either direction).

In three anomia treatment studies, Fillingham, Sage and Lambon Ralph (2005a, 2005b, 2006) found that no language scores correlated with therapy outcomes (for either errorless or errorful learning). However, certain cognitive tasks did, for example, the Camden Memory Test, the Wisconsin Card Sorting Test, immediate recall for the Rey Complex Figure Test and Recognition Trial, and monitoring (of their own naming performance). The authors suggest that those who responded best to both treatments, had better recognition memory, executive function and monitoring skills.

Consequently, it is possible that in order to be able to monitor responses and only reinforce correct responses, these cognitive skills are critical. In addition, our results from Paper 1 indicate that there is not a straightforward relationship between executive function and improvement – variability in naming accuracy is also required. Only when both of these are present is an individual likely to benefit from repeated naming attempts (or cumulative effects of repetition priming).

These preliminary findings warrant further investigation of whether, in combination with a measure of naming variability at an item level, the WCST task could serve as a screen for identifying who might benefit from independent repeated attempted naming, and for whom, feedback may be required in order to prevent incorrect responses being reinforced. Future research could usefully explore which of the wide range of skills required to successfully perform the Wisconsin Card Sorting Test is the most relevant aspect of cognition for predicting this ability to ensure only correct responses are reinforced.

Statistical Analysis & Power:

Whilst comparing various statistical techniques was not an aim of the current thesis; there were some noteworthy findings. The first point relates to issues comparing across different studies.

The majority of analyses in this thesis were conducted using linear mixed effects modelling (LME). Using this method of analysis allows the model to be fitted to each data point and account for both item and subject variance (Baayen, Davidson & Bates, 2008). As was discussed in Paper 3, the choice of analysis method can affect the results (and therefore the conclusions made in the literature). The exact reason for this difference is difficult to pinpoint from this study. It could be due to the within subject and item variability, or due to session effects, neither of which are accounted for using Analysis of Variance (ANOVA). Another difference in the current thesis from previous studies using ANOVA is the transforming of data to ensure that the assumptions of LME were met. In Papers 2-4 we used a logarithmic transformation to improve normality of the model's residuals. The logarithmic transformation of response times can change the results by reducing the size of the interaction (Balota, Aschenbrenner, and Yap, 2013). However, when this issue was explored by running the analyses in the studies presented here using other transformations (e.g., inverse Log) and using raw RT, the results were the same as reported in the papers. Therefore, this transformation is unlikely to be the source of the differences between our findings and previous studies.

The previous two studies mentioned in Paper 3 (Mitchell et al.,1990; Wiggs et al., 2006), both used ANOVA and found significant priming for all age groups at each delay (up to three or four weeks respectively). Mitchell et al. (1990) used raw response latencies, comparing primed items to control items in the same session. Wiggs et al. (2006) used proportional priming measures, to account for the difference in baseline naming across the age groups. Using these methods of analysis, our data found that the older adults did have significant priming at the one week delay. This is in contrast to the results found with the LME. This shows the importance of selection of appropriate statistical analysis for the data. Priming it turns out is highly variable, which is better accounted for using LME.

Implications for treatment:

The two papers on people with aphasia in this thesis (Papers 1 and 4) have shown that even without any treatment or feedback, some people with aphasia can improve their naming. Both papers provided evidence that for some people with aphasia, in order to improve accuracy without any treatment, repeated attempts are required. Given the variable nature of naming in people with aphasia, enough repetitions are required in order to successfully produce the target enough times to lead to strengthening of the response. It appears that this improvement can occur even at long intervals between repetitions.

Paper 1 suggested that the mechanism for improvement was the same for attempted naming over time as that underpinning effects of repetition priming. Although accuracy may vary, over time, when a correct response is produced (or possibly simply activated), this strengthens its lexical connections, increasing the likelihood it will be retrieved successfully on the following occasion. However, this does not take into account the possibility that incorrect responses may be reinforced as well.

In fact, Paper 1 found that for some people with aphasia, failed attempts can lead to a further decline in performance. By producing or activating the incorrect target word, the alternative (incorrect) response may be strengthened. The possibility that errors can be harmful for naming improvement has been explored in studies comparing errorful to errorless treatment. Errorless learning refers to the treatments which attempt to minimise the possibility that individuals make an incorrect response, by providing the participant the correct response before they attempt to retrieve it (e.g., Abel, Schultz, Radermacher, Willmes & Huber, 2005; Fillingham, Sage & Lambon Ralph, 2005a). While there has been debate in the literature regarding whether errorless learning may be more effective than errorful learning in other domains, until recently in anomia it has been consistently found that there was no evidence for a difference between the two tasks (e.g., Abel et al., 2005; Fillingham, Sage & Lambon Ralph, 2005a, 2005b; 2006). Our findings suggest that for some individuals making errors is detrimental. Moreover, in the larger study from which these data were drawn neither of these individuals improved as a result of treatment - either errorless (Repetition in the Presence of a Picture) or errorful (Semantic Feature Analysis) - hence even when given the correct response this is not enough to prevent the reinforcement of these responses.

With regard to the potential mechanism by which this priming occurs, and specifically whether an item needs to be retrieved or simply activated, in a recent study, Schuchard and Middleton (2018b) found that retrieval practice was more beneficial for strengthening all stages of the word retrieval process (compared to repetition which bypasses semantic connections). Moreover, Middleton, et al. (2015) found that despite being provided the correct target after all attempts, successful naming resulted in a greater benefit compared to failed attempts. It would be interesting to determine whether this effect was modulated by the cognitive skills of the participants as we found in Paper 1. However, errorless learning was found to be more beneficial than attempted naming, for deficits in access to the phonological form (Schuchard & Middleton, 2018a). The authors suggested that a pre-treatment screening for phonological errors could help identify who would most benefit from errorless learning.

This is in contrast to the results of Paper 1 where there was no relationship between level of impairment and improvement from attempted naming. To bridge the gap between these results, a future study could compare unaided naming either with no feedback, or with feedback, and an errorless approach.

There is some evidence that attempted naming could result in longer lasting effects compared to repetition treatment for some people with aphasia (Schuchard & Middleton, 2018b). By having to retrieve the name on their own, all phases of the retrieval process are activated and reinforced. In fact, in Paper 1, one of the individuals who benefited from repeated attempted naming, did not improve any further with treatment. While he did get better on treated items, this was found to not be in relation to times of treatment, and only due to repeated attempts. For some individuals, therefore, therapy could use more self-directed strategies, without the need for explicit feedback, such as the use of treatment apps. For example, Franklin and colleagues have developed a training app called SANTA (Self-Administered Naming Treatment App) which allows for individuals to select words to practice through repeated attempts (Franklin et al., 2015; Leahy, 2015). While for others, this unsupported practice could do more harm than good. The findings from Papers 1 and 4 have reinforced the importance of selecting the appropriate treatment for individuals with aphasia in order to make the most impact. Further research is required to find the best screening tests to determine what level of intervention participants require to receive the largest benefit.

Conclusion

Overall this thesis found evidence that some people with aphasia are able to improve their naming, through repeated attempts at naming. This has clear clinical relevance as some individuals do not require direct treatment to improve their naming, meaning improvements can be both time and cost-effective. However, for some individuals, repeated attempts without the presence of feedback, can lead to more harm than good. While not all people who benefit from treatment will benefit from repeated attempted naming, this thesis indicates they may still share the same underlying mechanism: a strengthening of lexical connections. While this thesis was not designed to determine the level at which priming was occurring, given the large variability both within and between individuals in unimpaired speakers, it is possible that priming is the result of multiple processes involved in word retrieval being improved. Furthermore, this thesis provides some evidence that some item-level variability as well as some aspect of executive functioning skills may improve the success of cumulative priming in people with aphasia. Over time the correct response is produced enough times to strengthen the response. Non-linguistic cognition may play a role in ensuring only correct responses are primed.

This body of work has contributed to the understanding of the mechanism underpinning treatment effectiveness and provides incentive to research repetition priming further in order to better understand which treatments may result in the greatest improvement for different individuals. More research on variability and cognition in people with aphasia may help to develop a useful screening tool to aid with this targeted treatment. This thesis also uncovers the need to further study repetition priming in unimpaired individuals in an attempt to further uncover the mechanism of priming and the process of word retrieval itself.

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Appendix

Ethics approval letter for research carried out
at Newcastle University, United Kingdom

Ethical Approval

Wendy Davison
Today, 15:37
Ella Creet (PGR); Julie Morris

Reply all

Dear Ella

Thank you for your application for ethical approval of your project "Spoken word production: how we retrieve words and what might help this". I confirm that Prof Daniel Zizzo has approved it on behalf of the Faculty of Humanities and Social Sciences Ethics Committee.

Please note that this approval applies to the project protocol as stated in your application - if any amendments are made to this during the course of the project, please submit the revisions to the Ethics Committee in order for them to be reviewed and approved.

Kind regards,

Wendy

Wendy Davison
PA to Lorna Taylor (Faculty Research Manager)
and Sue Mitchell (Research Funding Development Manager)
Faculty of Humanities and Social Sciences
5th floor, Daysh Building
Newcastle University
Newcastle upon Tyne, NE1 7RU

Telephone: 0191 208 6349
Fax: 0191 208 7001