Investigating the effects of short-term masked priming on recognition memory

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Carmen Florentina Ioniță

School of Biological Sciences, Division of Neuroscience and Experimental Psychology

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List of Abbreviations

ANOVA	Analysis of variance
BA	Brodmann area
CMS	Common mode sense
CR	Correct rejection
DCM	Dynamic causal modelling
DLPFC	Dorsolateral prefrontal cortex
DRL	Driven right leg
ICA	Independent component analysis
EEG	Electroencephalography
EOG	Electrooculogram
ERP	Event-related potential
FA	False alarm
MNI	Montreal Neurological Institute
ms	millisecond
MTL	Medial temporal lobe
N	Number of participants
PRC	Perirhinal cortex
ROI	Region of interest
RT	Response time
s	second
SD	Standard deviation
SPM	Statistical parametric mapping
η^2	eta squared
μV	microvolt

Abstract

Recognition memory decisions can be influenced by short-term masked priming. The overarching aim of the thesis was to investigate the effects of short-term repetition and conceptual priming on familiarity and recollection, respectively. Previous research has found that repetition priming of test stimuli (chair – CHAIR) increases familiarity regardless of the study status. Similarly, increasing conceptual fluency of test stimuli through associative priming (table – CHAIR) has been found to increase familiarity for both studied and unstudied stimuli. The convergent explanation for this phenomenon is fluency (mis)attribution to memory, with more fluently processed stimuli being judged as studied or familiar. One branch of the thesis investigated the on/off switching of the fluency attribution to memory system and the neural dynamics underlying it. In two experiments (Chapters 2 and 3) we found that fluency is attributed to prior exposure when study and test modalities match (at least partially). Memory- and priming- sensitive event-related potential (ERP) components were found, but these did not appear to capture the fluency attribution process (i.e., there were no group differences). However, using dynamic causal modelling (DCM), we found that group modulated the connectivity strength between right perirhinal cortex and right dorsolateral prefrontal cortex. The second branch of the thesis examined the mechanism underlying conceptual priming effects on recognition memory. Recent studies have reported that non-associative conceptual priming (sofa – CHAIR) increases correct recollection only. Rather than fitting the fluency-attribution-to-memory framework, we propose that these findings are due to encoding context reactivation, conceptual primes acting as retrieval cues for the encoded memory trace of the target word. In a series of experiments, we biased the encoded context of target words and used conceptual primes: (1) related to the target and to the encoded context, (2) related to the target and related to a different context (than the encoded one), and (3) unrelated primes. Conceptual priming effects on recollection were not consistently observed; nonetheless, only primes related to the encoded context increased recollection compared to the other priming conditions, supporting the encoding context reactivation account. In contrast, conceptual primes related to the different context, and sometimes both types of related primes increased familiarity compared to unrelated primes, in line with the fluency attribution account of familiarity. Overall, our findings show distinct mechanisms by which repetition priming and non-associative conceptual priming influence recognition memory judgments.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright statement

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Chapter 1: Introduction

The overarching aim of the present thesis is to investigate the effects of short-term masked priming on recognition memory. These effects sit at the boundary between implicit and explicit memory systems, often being an instance of the interaction between the two systems. Thus, the literature review will first introduce the two memory systems, what separates them and where they interact. Methods of measuring memory performance and the neural correlates of recognition memory will be reviewed. It will then focus on processing fluency: what it is, how it influences different decisions, and particularly, how it is related to recognition memory judgments. Methods of increasing processing fluency will be reviewed, and the focus will then go on short-term priming and how repetition, associative and conceptual priming of test stimuli affect recognition memory judgments. The review will close with remaining questions about repetition and conceptual priming effects on recognition memory and how the experimental work in the thesis will investigate these.

1.1. Implicit and explicit memory systems

The modern era of memory research began with the case of H.M. - an amnesic patient whose memory impairments following bilateral medial-temporal lobe resection were described by Scoville and Milner (1957). As pointed out by Squire and Wixed (2011), H.M.'s pattern of impairments provided the foundation of subsequent memory research. Apart from suggesting the crucial role of medial temporal lobes for retrieving past events as well as for forming new memories, H.M.'s spared working memory, perceptual and intellectual abilities indicated that these cognitive functions are not dependent on the damaged brain areas. Importantly, H.M.'s ability to learn new motor skills with practice, even without being aware that he was repeating the task, suggested the existence of multiple memory systems (Squire & Wixted, 2011). This idea of different memory systems has been further supported by reports of spared cognitive functions that could be associated with learning and memory in amnesic patients. In his review, Shimamura (1986) concluded that despite profound memory impairments, priming (i.e., biased performance on various tasks due to previous exposure to specific information) has been consistently reported to be preserved in amnesic patients. For instance, amnesic patients perform similarly to healthy controls on a word-stem completion task following presentation of a set of words, with increased likelihood of producing the previously encountered words when prompted with the first three letters (Graf & Schacter, 1985). Furthermore, when tested independently for the same study stimuli, amnesic patients show similar priming effects, but impaired recognition for the same set of studied words, relative to controls (Hamann & Squire, 1997; Levy, Stark & Squire, 2004).

Based on such patterns of results in amnesic patients, researchers distinguish between explicit or declarative and implicit or non-declarative memory systems (Graf & Schacter, 1985; Squire & Zola-Morgan, 1988). Declarative memory is episodic (i.e., autobiographical events) or semantic (i.e., knowledge about the meaning of the world) and encompasses information and knowledge that can be consciously recollected, whereas non-declarative memory involves acquisition of information or skills which are then implicitly reflected in improved or biased performance but are not available for conscious retrieval (Squire & Zola-Morgan, 1988). As initially suggested by H.M.'s case, declarative and non-declarative memory systems seem to rely on (at least partially) different neural networks, declarative memory mainly relying on the medial temporal lobes and diencephalon and non-declarative types of memory being associated with other regions such as the striatum for procedural memory or the neocortex in the case of priming (Squire, 2004). The literature review will later return to the neural bases of memory, after introducing refinements of cognitive measurements.

1.2. Measurement of memory

Memory performance is measured experimentally through direct and indirect tests (even in the same study, e.g., Graf & Schacter, 1985), direct memory tests assessing participants' ability to consciously remember previously presented information either through recall or recognition tasks and indirect tests assessing participants' biased performance on other tasks due to prior exposure to specific information (Johnson & Hasher, 1987). As they require participants to explicitly indicate whether a given event or stimulus has been encountered previously, recognition memory tests are ostensibly direct memory tests. However, indirect and direct memory tests are not necessarily process-pure, as suggested by Jacoby (1991) in the process dissociation framework he proposed, where recognition memory is conceptualised as relying on both automatic and intentional processes.

Researchers in the field have proposed a range of recognition memory models most of which distinguish between two kinds of memory that can support recognition: familiarity and recollection (see Yonelinas, 2002 for an extensive review). Familiarity refers to the experience of knowing a stimulus has been encountered previously in the absence of any contextual details about the encoding event, whereas recollection involves recognition of a stimulus and the ability to retrieve details about its encoding (Mandler, 1980; Tulving, 1985; Yonelinas, 2002). Recollection is thought of as a form of cued recall, presentation of a stimulus acting as a cue for recall of unique details about its encoding (Montaldi & Mayes, 2010), whereas familiarity involves a memory-matching process (i.e., between an encoded representation of a stimulus and its current presentation) initiated by the presentation of a stimulus and can be explained within the signal detection theory framework (e.g., Yonelinas, 1994).

Recognition memory tasks consist of two stages: *encoding* which involves participants being presented with a set of stimuli and *test* which includes both studied and non-studied stimuli. The most basic way to assess recognition memory is to require participants to make old/new judgments for each stimulus in the test list. However, as this does not provide information about different kinds of memory experiences, a range of more complex tasks has been developed such as the process-dissociation procedure (Jacoby, 1991), the receiver operating characteristic procedure (Yonelinas, 1994) or the R/K paradigm (Tulving, 1985). Each of them encompasses a set of assumptions about memory processes and has its own advantages and limitations (see Yonelinas, 2002).

Although results from studies using other paradigms will be presented, in the present review the focus will be on the R/K paradigm which is based on participants' subjective reports of their memory experience. It was proposed by Tulving (1985) and has been extensively used since then to measure familiarity and recollection. The classical version of the R/K paradigm involves making old/new judgments about a set of stimuli among which there are both studied items and non-studied items (that we will sometimes refer to as 'lures'). For test stimuli endorsed as 'old', participants are then prompted to make R/K judgments - R stands for Remember and K stands for Know - based on their memory experience. Participants are instructed to give R responses to test items for which they can recall any contextual details related to the encoding episode (e.g., the location in the study list, something they thought about when seeing the item) and K responses when they recognise the item as having been presented at study, but in the absence of any additional details about its previous presentation. In the analysis, R responses are associated with recollection and K responses with familiarity. Although the R/K paradigm has been criticised for potential memory strength confounds, with recollection as reflected in R responses potentially being just strong memory and familiarity as reflected in the K responses being weak memory (e.g., Wais, Mickes & Wixted, 2008), it provides a useful way to measure familiarity and recollection if care is taken to provide participants with clear instructions and to ensure they understand and follow them throughout the experiment (Migo et al., 2012). As we will see below, neuropsychology and neuroimaging evidence suggest the distinction between recollection and familiarity is more than one of strength or confidence, each kind of memory being associated with distinct brain areas.

1.3. Neural correlates of recognition memory

In terms of the neuroanatomy of recognition memory, it has been suggested that the perirhinal cortex processes object-related information and the parahippocampal cortex deals with context-related information (Diana, Yonelinas & Ranganath, 2007). Montaldi and Mayes (2010) argued that medial temporal lobe regions have different memory-related functions depending on the nature of input they receive from other brain regions, on their cytoarchitecture, on the way they process the input information and, also, on their interactions with other brain areas. The Convergence, Recollection and Familiarity Theory (CRAFT) (Montaldi & Mayes, 2010) proposes that the perirhinal cortex is involved in binding object information to form item-related memories and new object-object associations, whereas the parahippocampal cortex is involved in binding context information to form context-related memories. The memory representations at the level of parahippocampal and perirhinal cortices are thought to support experiences of familiarity. Within the same framework, the hippocampus is thought to be involved in binding item- and context-related information to form object-context associations; memory representations created at the hippocampal level are thought to support recollection. A different perspective on the neuroanatomy of recognition memory argues against distinguishing between familiarity and recollection, claiming that studies separating the two kinds of memory suffer from memory strength confounds, familiarity potentially being equivalent to weak memory and recollection with strong memory (Wixted, Mickes & Squire, 2010). However, Kafkas and Montaldi (2012) reported different patterns of neural activity associated with familiarity compared with recollection even when memory strength was matched, the perirhinal cortex selectively responding to familiarity and increased activity in the hippocampus being associated with recollection, but not with (strong) familiarity. Therefore, based on existing evidence, the experimental findings presented in the thesis will be written from a dual-process view on recognition memory.

Although explicit memory and implicit memory operate as distinct systems with different neural correlates (Squire, 2004), there are instances when they interact or overlap (e.g., Berry, Shanks & Henson, 2008). When reviewing the "porous boundaries" between implicit and explicit memory, Dew and Cabeza (2011) mentioned the difficulty to separate familiarity-based memory and conceptual priming, given their unavoidable interaction during standard recognition testing (i.e., at least partially, a familiarity-based memory judgment about a present stimulus will be based on its conceptual fluency due to prior exposure to it at study). Bader and Mecklinger (2017) tried to separate the event-related potentials associated with conceptual fluency and familiarity-based memory, by manipulating orthogonally the two processes. Their findings indicate a mid-frontal topography associated with familiarity and a more anterior (right-parietal) topographical distribution of conceptual fluency effects in the same 300-500m time window. Although it is still an open question to clarify what familiarity-based memory and conceptual priming share and not share in terms of underlying neural networks, their study suggested at least partial non-overlapping neural sources. Another proposal of the interaction between priming, as a form of implicit memory, and recognition, as a measure of explicit memory, was made by Jacoby and Dallas (1981). They argued that familiarity-based memory judgments are made through unconscious attribution of processing fluency to prior encounter of a given stimulus. The next section will elaborate on the concept of processing fluency and will present instances in which fluency derived from priming is attributed to memory.

1.4. What is fluency and what are the different types of fluency?

In general terms, processing fluency is the ease or speed of processing information. Researchers often distinguish between perceptual and conceptual fluency, the former referring to ease of processing a stimulus based on its physical features and the latter to ease of processing a stimulus based on its meaning (Simon et al., 2016; Willems & Van der Linden, 2006; see Alter & Oppenheimer, 2009 for an extensive review on types of fluency). Perceptual fluency can be influenced by a range of display characteristics such as visual clarity (e.g., a clear Arial font is processed more fluently than **a condensed Impact font** (Alter & Oppenheimer, 2008), exposure time with longer display duration enhancing the processing fluency (e.g., Reber, Winkielman & Schwarz, 1998), or priming (e.g., preceding the presentation of a stimulus with a matching contour increases processing fluency (Winkielman & Cacioppo, 2001)). Conceptual fluency can be increased, for instance, by presenting semantically related word pairs which are processed faster compared to unrelated word pairs, effect known as semantic priming (Meyer & Schvaneveldt, 1971).

1.5. How does fluency affect human reasoning?

As emphasised by Schwarz (2004) in his review, people make judgments, in general, on the basis of a complex interplay between declarative information they can access (i.e., content), their subjective experience (e.g., ease of thought generation or processing fluency of external information), perceived value of these experiences (e.g., whether their source is relevant for the task or not) and individuals' naïve theories of cognition (i.e., subjective assumptions people hold about how their cognition works) which are employed to interpret these experiences. Importantly, researchers have highlighted the role of processing fluency as a metacognitive cue in human reasoning (e.g., Alter & Oppenheimer, 2009; Schwarz, 2004; Reber, Schwarz & Winkielman, 2004), which means that the ease of processing a stimulus will influence a judgment alongside the declarative information people can access. For instance, processing fluency and its perceived value for the judgment task influence people's decisions about whether a statement is true or not (e.g., Reber & Schwarz, 1999), about attractiveness of a stimulus (e.g., Reber, Schwarz & Winkielman, 2004) or about prior exposure to a stimulus (e.g., Jacoby & Whitehouse, 1989). In terms of the role processing fluency plays in recognition memory judgments, when people are required to decide whether a given stimulus has been studied, they presumably base their memory judgments on the encoded memory trace associated with the stimulus (declarative information), on how fluently they processed the stimulus (subjective experience) and on whether they consider the processing fluency a valuable cue or not (perceived value of the subjective experience). In memory experiments using fluency manipulations, perceived value of the processing fluency of test items may partly depend on participants' ability to correctly attribute it to its correct source, as will be detailed in the next section. Hence, if they are not aware of the experimental manipulations of fluency, they are likely to attribute fluency to prior exposure to the stimulus. This likelihood is further increased in the absence of recall of contextual details associated with a given test stimulus, as emphasised by Kelley and Rhodes (2002) in their review about fluency attributions to memory.

The role of processing fluency in memory decisions was first acknowledged by Jacoby and Dallas (1981) when they distinguished between remembering based on perceptual fluency during the task and more elaborative remembering when participants could retrieve contextual details of the encoding episode. Later, experimentally manipulating perceptual fluency through short-term repetition priming of test items, Jacoby and Whitehouse (1989) found increased rates of false alarms for words preceded by matching primes (i.e., same as the target) compared to words preceded by non-matching primes (i.e., different from the target), effect which has come to be known as the 'Jacoby-Whitehouse memory illusion' and which generated a whole body of research investigating fluency (mis)attribution to memory. Researchers tried to understand the phenomenon by varying different experimental factors such as participants' awareness of the experimental manipulation of fluency (e.g., Joordens & Merikle, 1992; Klinger, 2001), exposure time to primes (e.g., Huber, Clark, Curran & Winkielman, 2008), or item presentation frequency in the encoding (Kinoshita, 1997; Lloyd et al., 2003). Similar patterns of results have been reported when increasing conceptual fluency of the test stimuli (e.g., Dew & Cabeza, 2013; Rajaram & Geraci, 2000). In the next subsections, the review will focus on different aspects of fluency attribution to recognition memory.

1.6. Perceptual fluency and memory

Perceptual fluency of test items in memory tasks has been manipulated by increasing the contrast of certain stimuli (Willems & Van der Linden, 2006), using different pools of letters for target words and lures (Bastin, Genon, & Salmon, 2013; Keane, Orlando & Verfaellie, 2006; Parkin et al., 2001; Simon et al., 2016) or preceding the test stimuli with their own brief presentation (e.g., Duke, Fiacconi & Köhler, 2014; Jacoby & Whitehouse, 1989; Rajaram, 1993). Regardless of the method used to experimentally increase perceptual fluency, it has been consistently reported that in certain circumstances which will be elaborated on in this section, fluency of test items is attributed to memory. Simply put, stimuli that are perceived fluently are judged as having been studied in the encoding episode of the memory task. In this section, findings will be first grouped based on the method of manipulating perceptual fluency and special attention will be given to repetition priming. Then, effects of perceptual fluency on familiarity and recollection judgments, as well as on confidence ratings of memory will be discussed and finally, results from EEG studies investigating fluency and memory judgments will be presented.

1.6.1. Methods of manipulating perceptual fluency

Contrast changes

Using line drawings of unfamiliar 3D objects as stimuli in an incidental study phase, Willems and Van der Linden (2006) manipulated perceptual fluency of target stimuli in a forced-choice recognition task using contrast changes. High-contrast (+) stimuli were presented in white on a black background whereas low-contrast (-) stimuli suffered a more (10/20%) or less subtle (40%) contrast reduction in a series of three experiments. Each target stimulus appeared with a distractor that could also be either high- or low-contrast. Thus, four types of trials resulted from the contrast manipulations: Target+/Distractor+, Target+/Distractor-, Target-/Distractor+, Target-/Distractor-. Their findings indicate that when contrast manipulations were subtle (i.e., 10% or 20% contrast reduction), rendering participants unaware of the fluency source for the high-contrast stimulus in the pair, recognition performance showed a large effect size for Target+/Distractor- trials (i.e., in the pairs where the relative perceptual fluency of the target was higher than that of the distractor). However, in the final experiment when low-contrast stimuli were presented with 40% contrast reduction (i.e., obvious contrast manipulation), the recognition performance advantage of Target+/Distractor- trials was reduced, suggesting that participants' ability to correctly attribute perceptual fluency to the contrast changes reduced their reliance on processing fluency when they made memory judgments.

Letter-level fluency

Another way to manipulate perceptual fluency was proposed by Parkin et al. (2001) who used different sets of letters for target words and lures in a recognition test. In a so-called no-overlap (NO) condition, studied words and lures were made up of letters extracted from two different pools and in the baseline overlap (O) condition, studied words and lures were composed of letters drawn from the entire alphabet. Thus, in the NO condition recognition accuracy is expected to be higher compared to the baseline condition, as the letter-level fluency manipulation increases the salience of target words and decreases the interfering effects of lures. Parkin et al. (2001) explored age-related differences in the use of fluency heuristics in memory judgments. This discrete experimental manipulation of perceptual fluency yielded interesting results, older participants showing significantly fewer false alarms in the NO condition relative to the O condition compared to young participants. Their findings show that elderly were more likely than young adults to benefit from this increase in fluency cues which decreases the probability of false recognition. This age group difference could potentially be explained through the fact that recollection is impaired in elderly, while processing fluency is more likely to be used as a cue for prior exposure in the absence of details about the encoding episode, as suggested by Kelley and Rhodes (2002).

Using the technique developed by Parkin et al. (2001) to manipulate perceptual fluency, researchers investigated whether increasing the salience of target words in memory tests could compensate for memory impairments due to Alzheimer's Disease (AD) (Bastin et al., 2013; Simon et al., 2016), or amnesia due to other causes (Keane et al., 2006). Overall, letter-level fluency improved patients' recognition accuracy suggesting that when individuals cannot recollect the study episode, they are likely to rely on fluency cues in their memory judgments. However, patients still performed significantly worse than matched controls suggesting that these fluency manipulations cannot compensate their memory impairments.

<u>Repetition priming</u>

Repetition priming is the phenomenon by which prior exposure to a stimulus has a facilitatory effect on cognitive processing of subsequent presentation(s) of the same stimulus (Fleischman, 2007). Long-term repetition priming has been extensively used in implicit memory tasks and findings indicate that prior exposure to a stimulus facilitates its perceptual identification in degraded conditions (e.g., Hamann & Squire, 1997). Another task used to test implicit memory is word stem completion which involves cueing participants with first letters of a word and requiring them to generate a word. As a result of repetition priming, participants are more likely to generate words they have been exposed to previously in the task than other words (e.g., Graf & Schacter, 1985; Hamann & Squire, 1997). Although repetition priming is more often associated with implicit memory tasks as the ones reported above, it is important to note that the focus in the present thesis will be on the use of repetition priming in direct memory tests as will be detailed in the next subsection.

1.6.2. Terminology

The concept of *repetition priming* will be used for the experimental manipulation of preceding a stimulus in the test phase of a memory task with its own presentation. The stimulus preceding the presentation of a target will be referred to as *prime,* matching primes are the same as the target stimulus and non-matching primes are different stimuli, unrelated to the targets. Consequently, target stimuli preceded by matching primes will be referred to as *primed* and those preceded by non-matching or baseline (e.g., strings of characters: xoxoxo) primes will be referred to as *unprimed*. The priming effect refers to the situation when primed test stimuli elicit different responses compared to unprimed test stimuli. This difference can be in terms of memory-related responses (e.g., a higher proportion of "old" responses given to primed compared to unprimed stimuli), of response times (e.g., faster response times for primes compared to unprimed stimuli) or electrophysiological responses (e.g., higher amplitudes of event-related potentials associated with primed compared to unprimed stimuli).

Masking a briefly presented word by presenting another stimulus in the same location and in close temporal proximity makes the word 'invisible' or impossible to be processed consciously, though it is clear that they are processed unconsciously given their effects on decisions made to downstream stimuli (Dehaene et al., 2001). Studies using repetition priming in direct memory tests often involve masking the primes to reduce their visibility given the fact that participants' awareness of the primes can reduce the effects of repetition priming (e.g., Jacoby & Whitehouse, 1989). Masks can be random strings of characters (e.g., >£$%@^&#<, >########<) when test stimuli are words (e.g., Joordens & Merikle, 1992) or visual noise masks when pictures are used as stimuli (e.g., Duke et al., 2014). These masks can be displayed before exposure to a prime (i.e., forward mask or pre-mask) or after the prime (i.e., backward mask or post-mask) or both before and after the prime (see Figure 1 for an example of procedure using masked repetition priming).

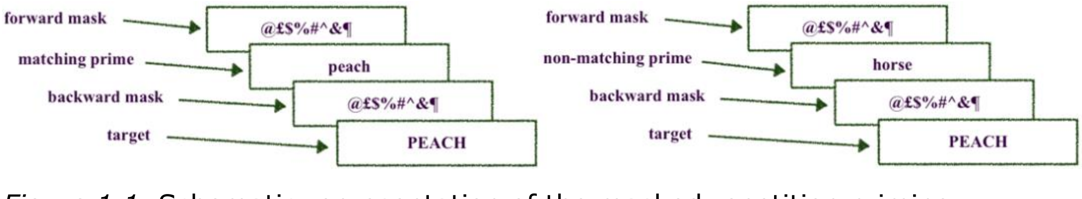


Figure 1.1. Schematic representation of the masked repetition priming procedure*.* Left: an example of primed trial, Right: an example of unprimed trial

1.6.3. The Jacoby-Whitehouse paradigm

Using repetition priming in the test phase of a recognition memory task, Jacoby and Whitehouse (1989) created a memory illusion where participants made more "old" responses to primed compared to unprimed lures. Importantly, the illusion only occurred with brief, subliminal repetition priming (16 or 50 ms prime display duration) when participants were not aware of the source of perceptual fluency they experienced. These findings have been interpreted as non-mnemonic fluency being attributed to memory: primed words were more fluently processed than unprimed words and, in the absence of information about the actual source of fluency (i.e., repetition priming), they were endorsed as "old". When participants were informed about the priming procedure and, in addition, the duration of primes was increased (to 250 or 600 ms) the repetition priming effect disappeared. According to the authors' interpretation, being aware of the primes, participants did not base their memory judgments on perceptual fluency anymore, since they correctly attributed the ease of processing primed words to the priming manipulation (Jacoby & Whitehouse, 1989). A lack of awareness of primes seems to be important for fluency misattributions to memory not only in the case of words as shown by Jacoby and Whitehouse, but also when pictures were used as stimuli (Duke et al., 2014). In a face recognition memory task, Duke et al. (2014) used masked repetition priming and found that participants who reported being unaware of the primes, but not participants who reported having had noticed the primes, were susceptible to the Jacoby-Whitehouse memory illusion.

1.6.3.1. Awareness, attention or exposure time?

Jacoby and Whitehouse (1989) argued that awareness of the primes plays a crucial role for fluency attributions to memory as described above. However, their argument could be challenged because in addition to different instructions given to participants regarding the existence of context words, they varied prime duration, long duration primes being used in the aware group and short duration primes being used in the unaware group. Consequently, as pointed out by Klinger (2001), varying the exposure time to primes also led to different prime-target stimulus onset asynchronies (SOAs) in the two groups. To control for these potential confounding differences, Klinger held the exposure time to primes and the prime-target SOA constant and manipulated the visibility of primes. He found that masked matching primes had a significant effect on memory judgments increasing false alarms (FAs) compared to non-matching primes, but this priming effect was not significant among participants in the 'unmasked' group. Klinger further explored the role of participants' attention for the primes in a second experiment. He revealed that unattended primes in the unmasked condition did influence memory judgments for lures, similar to the masked primes. In contrast, attended unmasked primes exerted an opposite effect, with significantly fewer FAs for test words preceded by matching compared to non-matching primes. Thus, Klinger argued that it is attention directed to the primes rather than the lack of masking that can diminish the priming effects on recognition memory. Nonetheless, masking can ensure participants are not likely to attend to the primes or to a proportion of primes which would confound the results. In another experiment, Bernstein and Welch (1991) replicated the Jacoby-Whitehouse effect for short duration primes both among participants who were not informed about the existence of primes and among participants who were informed about the primes. In this experiment, participants who were informed about the primes, were actually required to make judgments about the similarity between primes and target words (i.e., whether they were the same or different, or whether the prime was a non-word). They found an increased proportion of 'old' responses assigned to test words preceded by matching versus non-matching primes both for studied and new stimuli regardless of participants' awareness of the primes, measured as their accuracy on the prime-related task. Based on this, Bernstein and Welch (1991) argued that participants' lack of prime awareness is not a necessary condition to induce the Jacoby-Whitehouse memory illusion, as participants in their study experienced it while perceiving the primes (i.e., indicating 'same' or 'different' above chance). One potential limitation of this interpretation, as pointed out by Gellatly, Banton and Woods (1995) is that it is very likely that participants in Bernstein and Welch's experiment might have made the 'same'/'different' judgments based on perceived fluency and not based on their ability to actually identify the primes. This interpretation is supported by the fact that participants did not make 'non-word' judgments above chance (.31) which may suggest that they did not necessarily process the primes and could have based their judgments about primes on perceptual fluency which is not different from Jacoby and Whitehouse's interpretation. In their study, instead of presenting only one (matching or non-matching) word before the target, Gellatly et al. (1995) presented a rapid, but not subliminal, sequence of words (4 per second, with 50 ms interstimulus interval) which either contained a matching prime in the middle of the sequence or an unrelated word. Participants in the low-salience group were required to attend to the sequence of words and to make a memory judgment about the target word which appeared after the priming sequence, whereas participants in the high-salience group had to attend to the sequence of words, make a judgment on whether there was a word matching the target or not within the sequence, and then to make a memory judgment about the target word. They found repetition priming effects in the low-salience group but not in the high-salience group, similar to Jacoby and Whitehouse's (1989) results in the unaware and aware groups, respectively. Therefore, Gellatly et al. proposed that salience of the prime-target overlap and not the subliminal presentation of the primes, is crucial for the repetition priming effects, participants experiencing the illusion even though they perceive the primes but are not aware of the prime-target overlap.

To explore the potential confounding effect of exposure time to primes, Joordens and Merikle (1992) manipulated participants' awareness of the primes through the instructions given (i.e., either informing them about the primes, in the aware group, or not informing them, in the unaware group) and holding the prime duration constant (57 ms). They found a similar repetition priming effect on false alarms in both the aware and the unaware group. In a subsequent experiment, they informed participants about the primes and varied prime duration (57 ms & 228 ms) within-subjects, showing that FA rates were increased for primed words compared to unprimed words in the short prime duration condition only. Thus, Joordens and Merikle argue for the importance of exposure duration to primes in fluency misattributions to memory, with lures preceded by matching primes being more likely to be endorsed as 'old' relative to unprimed lures when prime duration is short, the opposite effect being observed when prime duration is long. Additionally, in another study, Merikle and Joordens (1997) indicated that in conditions of divided attention (i.e., when participants had to perform a secondary digit-monitoring task during the memory test), even for long exposure time to primes (114 ms), participants show the same pattern of results as in the case of short prime duration (57 ms), with more FAs for lures preceded by matching versus non-matching primes. Huber et al. (2008) proposed a fluency-disfluency model of priming effects dependent on prime duration, with short exposure to primes increasing processing fluency of test items and long exposure to primes being explained in terms of a disfluency effect through habituation. Arguably, Gellatly et al.'s (1995) conclusion about the importance of participants' awareness of the match between prime and target provides a pertinent explanation for these findings, participants being less likely to perceive the prime-target match in the short prime duration condition relative to long duration prime condition (Joordens & Merikle, 1992) or with short prime-target SOA compared to long prime-target SOA (Huber et al., 2008), as well as in the divided-attention condition relative to the focused condition even for long exposure time to primes (Merikle & Joordens, 1997).

To summarise, it might not be participants' awareness of the primes that modulates fluency attributions to memory as proposed by Jacoby and Whitehouse (1989), but their awareness of the fact that perceived fluency of test items preceded by matching primes is due to the experimental manipulation. In their review, Kelley and Rhodes (2002) stated that as individuals' ability to accurately attribute their perceived fluency of test items either to the experimental context, to perceptual features of the stimulus, to other potential experimental manipulations or to actual prior experience of the stimulus increases, the likelihood of experiencing memory illusions as the Jacoby-Whitehouse one is less likely. In the case of repetition priming, to be able to accurately attribute perceptual fluency to the prime-target overlap, exposure time to primes seems to be important as well as prime-target SOA (e.g., Huber et al., 2008; Joordens & Merikle, 1992). In addition, cognitive resources allocated to prime perception (Merikle & Joordens, 1997) and directed attention to primes (e.g., Gellatly et al.,1995; Klinger, 2001) can influence participants' ability to correctly attribute their perceived fluency of test items.

1.6.3.2. Expectations about the amount of fluency

Apart from prime awareness, prime duration and attention to primes, fluency attributions to memory are also influenced by the amount of fluency participants experience and its relevance for memory judgments. For instance, when the study episode involves multiple presentations of the same target words participants are less likely to attribute the perceptual fluency induced by masked repetition priming to memory when they are tested immediately after encoding; however, when the memory test is administered 48 hours after encoding, participants are prone to the Jacoby-Whitehouse illusion (Lloyd et al., 2003). These findings were explained in terms of changing participants' expectations about the amount of perceptual fluency that could be attributed to prior exposure to a stimulus, repeated presentations of a word in the encoding phase increasing the amount of fluency participants would attribute to memory when tested after a short delay (Lloyd et al.). In a subsequent experiment, Lloyd et al. used encoding lists containing words presented once or five times and found that regardless of the number of presentations during the study episode, participants showed repetition priming effects in an immediate memory test. This suggests that due to the once-presented stimuli in the study list participants had a lower 'threshold' for the amount of fluency associated with prior exposure, thus they accepted the fluency induced by repetition priming as attributable to memory (Lloyd et al.). These findings indicate that people adjust their expectations about perceptual fluency associated with prior exposure depending on the study context and attribute processing fluency due to masked repetition priming to memory when it corresponds to the expected amount.

1.6.3.3. Expectations about the relevance of fluency

Another factor that influences fluency attributions to memory is its relevance for prior exposure judgments. A series of studies investigated the effect of increasing processing fluency through repetition priming by manipulating the study-test perceptual match. Westerman et al. (2002) found that when they used auditory study lists and visual memory tests, participants did not show priming effects, suggesting that they did not find perceptual fluency in the visual modality relevant for prior exposure to auditory words. However, when the study lists included both auditory and visual words, participants attributed perceptual fluency of test words presented visually to prior exposure regardless of the study modality (Westerman et al., 2002). In an additional experiment Westerman et al. (2002) presented participants in one group with visual noise and participants in another group with auditory noise claiming that they are exposed to subliminal presentation of words. In the subsequent 'memory' test which used repetition priming, participants were instructed to make old/new judgments to indicate which words seem familiar. Their findings revealed that the priming effect was significantly stronger in the visual group relative to the auditory group, suggesting that expectations about the relevance of fluency for memory judgments modulate participants' likelihood to attribute processing fluency of stimuli to prior exposure.

Similarly, although the encoding list and the memory test were presented in the same modality, when participants studied pictures (each corresponding to one specific word) and then were tested for words, they did not attribute fluency induced by repetition priming to prior exposure to the concept (Westerman et al., 2003). Also, even when both the encoding and the test lists contained words which were presented either in the same font (Arial, 14, black) or using a different font (Comic Sans MS, 56, red) in the encoding, participants who studied words in a different font did not use the processing fluency induced by repetition priming as a cue for memory (Westerman et al., 2003). However, when participants studied words in both fonts and then were tested using one of the fonts, they showed priming effects of similar magnitude for words studied in the same font as the one used in the test list and for the words studied in a different font (Westerman et al., 2003). All these findings suggest that fluency attributions to memory are influenced by participants' perceived relevance of the fluency cue which is modulated by the study context and the encoding-test perceptual match.

A common example used to illustrate how perceptual fluency is experienced and attributed to memory in everyday life is to imagine a face popping out of a crowd (i.e., by being processed more fluently than other faces) which one might think is a familiar face of someone known (i.e., fluency attribution to memory). Experimentally manipulating the proportion of primed stimuli in the test list, Westerman (2008) found an increased magnitude of the priming effect with decreased proportion of primed trials. Additionally, when priming was manipulated between-groups with one group having all test words preceded by matching primes and the other group being presented only target words preceded by non-matching primes, no priming effect was found (Westerman, 2008). However, when half of the trials were preceded by matching primes and half preceded by non-matching primes, participants attributed the fluency induced by repetition priming to memory (Westerman, 2008). Westerman's (2008) findings suggest that using perceptual fluency as a cue for prior exposure depends on the context of the test list, repetition priming effects being more likely to occur when the primed test items 'pop out' among the unprimed items. Along the same lines, using kaleidoscope images rather than words, Wang et al. (2020) found that masked repetition priming affected memory judgments when primed and unprimed trials were randomly interleaved in the same block, but not when they were presented in separate experimental blocks. Manipulating fluency through clarity rather than repetition priming, similar results were reported, with recognition judgments being affected by fluency manipulations when fluent/non-fluent trials were randomly presented and not blocked (Gomes, Mecklinger & Zimmer, 2017; Leynes & Zish, 2012). Presumably the amount of perceptual fluency experienced by participants for each individual fluent trial is similar regardless of the proportion of fluent trials within a test list; however, given the fact that participants know the test lists contain studied and non-studied items, the informational value of processing fluency for discriminating between targets and lures might be decreased when all test items are being processed with the same amount of fluency.

1.6.4. Fluency effects on familiarity and recollection

So far fluency attribution to memory has been discussed without separating between different types of memory experience. As mentioned in the introduction, the dominant view on recognition memory assumes the existence of two kinds of memory: familiarity and recollection (Yonelinas, 2002). Using the R/K paradigm or adjusted versions of it, researchers have consistently reported that repetition priming selectively increases K responses, but not R responses, for both studied and non-studied test items (e.g., Kinoshita, 1997; Kurilla & Westerman, 2008; Rajaram, 1993; Taylor & Henson, 2012; Taylor et al., 2013; Woollams et al., 2008). These findings suggest that familiarity-based memory judgments are more likely to be influenced by processing fluency cues than recollection-based memory, in line with the argument that memory judgments are more likely to be based on fluency heuristics in the absence of more 'diagnostic' cues such as recollection of the encoding episode (Kelley & Rhodes, 2002).

When familiarity and recollection were measured using a modified version of the R/K paradigm which also included 'guess' as a response option alongside K and R, the repetition priming effect was observed only on 'guess' responses for non-studied items (Tunney & Fernie, 2007). Although this may seem to suggest that fluency manipulations using repetition priming only influence participants' memory judgments when they are guessing or intuiting their responses, it is nonetheless difficult to interpret the memory experience underlying 'guess' responses. Migo et al. (2012) proposed in their review that 'guess' responses could be associated either with low confidence familiarity, probabilistic judgments unrelated to memory or a mix of the two. In addition, they suggested that adding the 'guess' response category also adds complexity to the task, being rather difficult to instruct participants about its use.

In a forced-choice recognition task (i.e., participants had to choose between 2 stimuli which one appeared at study) with contrast manipulations to induce fluency, participants gave more K responses for trials in which the studied items had a higher contrast than the lure when the contrast differences were subtle but not when they were obvious (Willems & Van der Linden, 2006). These findings suggest that familiarity-based judgments may be influenced by processing fluency which is attributed to prior exposure only when viewers were not aware of its specific sources - in this case, of contrast manipulations. Although awareness of the fluency source seemed important for participants' perceived value of the fluency cues for memory judgments, when contrast differences were subtle, participants did not make K false alarms for trials in which the distractor had a higher contrast than the target. Interestingly, when perceptual fluency is manipulated in a forced-choice recognition task, participants use fluency cues to successfully discriminate between studied and non-studied items and are not prone to memory illusions due to increased fluency of lures as observed when using the classical R/K paradigm.

In terms of the effect of perceptual fluency on R responses, Willems and Van der Linden (2006) reported that trials in which the target had a higher contrast than the lure received more R responses compared to the other trial types both when the contrast differences were subtle and when they were obvious. Due to the fact that this study used a forced-choice task, its results are not directly comparable with those of studies using the R/K paradigm, but these findings suggest, nonetheless, a link between fluency and recollection. Park and Donaldson (2016) have recently reported an effect of masked repetition priming on R response times using the R/K paradigm in the absence of any priming effects on K or R response rates. Also, using independent ratings of familiarity and recollection, Kurilla and Westerman (2008) found that repetition priming increased ratings of both K and R. Therefore, although the effect of increasing perceptual fluency on K responses or familiarity judgments has been consistently reported, the relationship between perceptual fluency and R responses or recollection-based memory judgments is less clear and awaits further clarification.

1.6.5. Perceptual fluency and confidence ratings of memory

Results of studies investigating the effect of processing fluency induced by repetition priming on confidence ratings of memory are not consistent. When participants were prompted to choose from 'sure'/'unsure'/'guess' response options after making memory judgments in a classical old/new recognition memory task, lures preceded by matching primes received more 'unsure' responses compared to unprimed lures (Tunney & Fernie, 2007). This suggests that perceptual fluency is attributed to memory when participants intuit their response, as the effect was observed only for new but not for studied items. In another study, when participants had to indicate their level of confidence at the same time as judging whether the item was studied or not (i.e., they had to choose from 'high confidence old', 'low confidence old', 'low confidence new', 'high confidence new') they made more high confidence false alarms for primed lures relative to unprimed lures (Lucas et al., 2012). Previously described studies reported masked repetition priming effects selectively on familiarity as suggested by the effect on the rate of K responses. Given that familiarity strength can vary (see Kafkas & Montaldi, 2012), priming could have an effect on both high and low confidence memory judgments depending on the nature of memory experience.

Rajaram (1993) found different patterns of effects of repetition priming using the R/K paradigm and confidence ratings, in separate experiments. On one hand, repetition priming increased K responses for both studied items and lures and, on the other hand, it increased both high confidence and low confidence false alarms. If perceptual fluency cues are attributed to familiarity, which can vary in strength, then it is unlikely to see a consistent pattern of results when investigating the effect of repetition priming on confidence ratings without distinguishing between familiarity- and recollection-based memory judgments. A potential way to do so would be to use an adjusted version of the R/K paradigm which encourages familiarity-based memory judgments, allowing different levels of familiarity strength (F1, F2, F3) and one response option for unintentional recollection (Montaldi, Spencer, Roberts & Mayes, 2006). Based on previous findings, repetition priming would increase familiarity responses overall, but not recollection-based responses and its effect on confidence ratings could then be explored by looking at different familiarity strengths.

1.7. The effect of conceptual fluency on memory judgments

Conceptual fluency of test items has been experimentally increased using either brief associative priming (Dew & Cabeza, 2013; Rajaram & Geraci, 2000) or predictive sentence stems (e.g., Kurilla, 2011; Kurilla & Westerman, 2008; Westerman, 2008; Wolk et al., 2004). Generally, increasing conceptual fluency has yielded similar results to increasing perceptual fluency (e.g., Westerman, 2008). It is necessary to mention at this point that due to qualitative differences in the pattern of results described in this literature review, it is important to distinguish between associative priming and pure conceptual priming (see Figure 1.2). Associative priming refers to experimental manipulations involving prime-target pairs which have high free association rates (e.g., doctor-nurse), thus being lexically associated with high probability of co-occurrence in language (see Nelson, McEvoy & Schreiber, 2004), whereas conceptual priming (e.g., vaccine-nurse) will be used for instances when prime-target pairs are conceptually related but not lexically associated, as described by Taylor and Henson (2012).

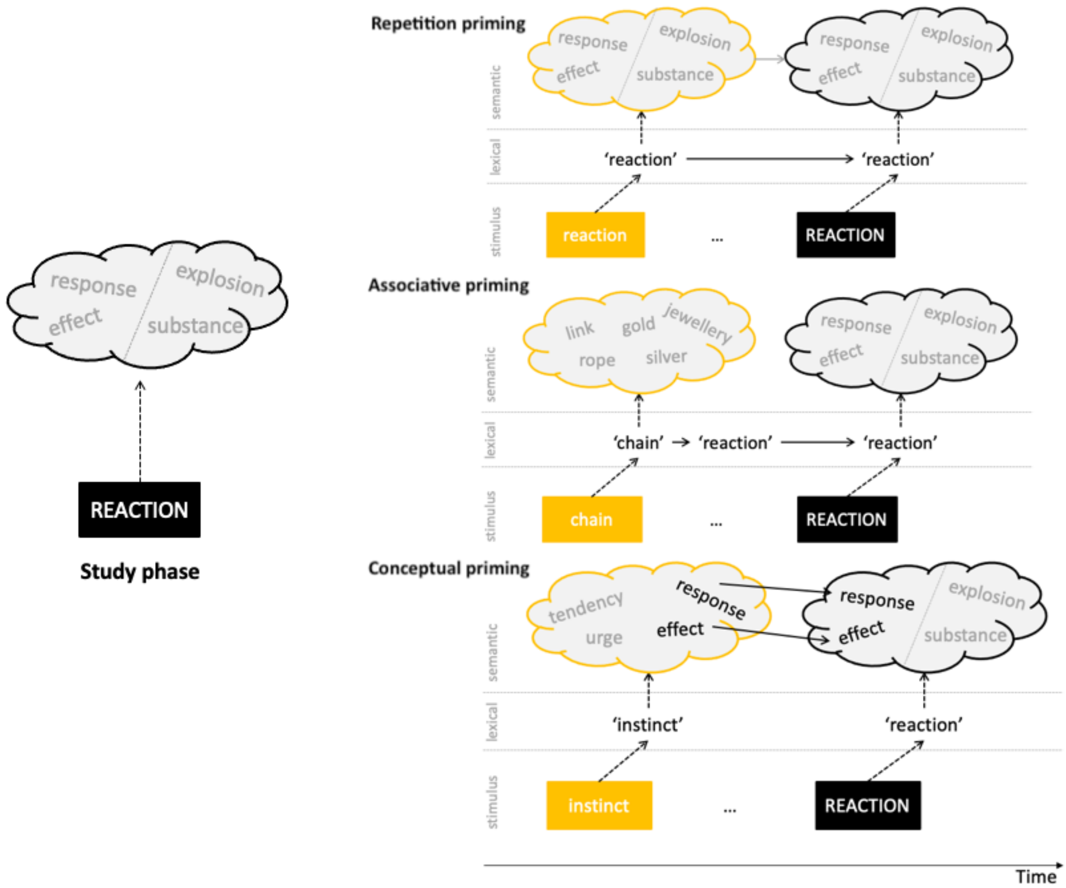


Figure 1.2. Visual representation of different types of priming. Left: In the study phase, participants may spontaneously generate conceptually related concepts to the target. Right top row: through repetition priming, the target is 'pre-activated' directly by the prime. Right middle row: through associative priming, the target is 'pre-activated' indirectly by the prime, given that it is very likely that the lexically associated word will come to mind. Right bottom row: through non-associative conceptual priming, the prime activates some of the same semantic concepts generated by participants at study.

Several studies investigated the effect of increasing conceptual fluency of test words by preceding them with predictive versus non-predictive sentence stems. For instance, for the target word 'permit', a predictive sentence stem is 'You can only drive after obtaining a learner's …' and a non-predictive sentence stem would be 'I had to go to the other room to get my . . .' (Kurilla & Westerman, 2008). Using this method to manipulate conceptual fluency, an increased rate of 'old' responses has been reported for test words in the predictive condition relative to the non-predictive condition (Westerman, 2008; Wolk et al., 2004). Similar to the effect of repetition priming on memory judgments, conceptual priming effects as induced by predictive sentence stems were sensitive to encoding-test modality change, test words preceded by predictive sentence stems receiving more 'old' responses compared to words preceded by non-predictive sentence stems only when the study list and the test were presented in the same modality (Kurilla, 2011). Additionally, predictive sentence stems produced a similar pattern of results as masked repetition priming when the proportion of 'predicted' trials was manipulated, with an increased priming effect when the number of 'predicted' trials decreased (Westerman, 2008). When memory judgments were made independently for familiarity and recollection, predictive sentence stems preceding test words increased both recollection and familiarity ratings compared to non-predictive sentence stems (Kurilla & Westerman, 2008). However, it is difficult to interpret familiarity/recollection independent memory judgments because it is not clear what familiarity rating actually mean for words where recollection is strong, considering that familiarity is recognition without recall of any encoding details (Migo et al., 2012).

More similar to the repetition priming procedure introduced by Jacoby and Whitehouse (1989), Rajaram and Geraci (2000) used associative priming as described at the beginning of this section with the R/K paradigm. Their findings indicate an increased rate of K responses for both studied and non-studied test words in the primed relative to the unprimed condition. Noteworthy, exposure time to primes was supraliminal (150 ms) and given that Rajaram and Geraci did not use a masking procedure and that there was a 100 ms blank screen displayed between the prime presentation and the target word, primes were easily distinguishable by participants. However, the prime-target SOA was relatively short (i.e., 250 ms) which arguably led to automatic processing of primes (Neely, 1977), not allowing participants to strategically use the primes in their memory decisions (e.g., by identifying the lexical association between matching primes and targets). Another study using associative priming found an increased rate of 'old' responses and perceived oldness (measured through confidence ratings ranging from 1 = 'high-confidence new' to 6 = 'high-confidence old') for both studied and non-studied words that were preceded by related primes compared to test words preceded by unrelated primes (Dew & Cabeza, 2013). Although Dew and Cabeza did not use masks, target words were displayed immediately after the primes (SOA = 40 ms) to reduce prime visibility. The results reported in these two studies show similar patterns with the effect of repetition priming on memory judgments, conceptual fluency of test words, this time, being attributed to prior exposure for both studied and non-studied items.

1.8. A framework to interpret fluency attribution to memory

Rather than a simple mapping between fluently perceived stimuli being endorsed as 'old', Whittlesea, Jacoby and Girard (1990) proposed a complex attribution process where fluency is interpreted as evidence of prior exposure only in the absence of other apparent sources, when participants are required to focus on the old/new status of the stimulus, and in a context where fluency is salient to participants. In a series of experiments (Whittlesea & Williams, 1998) fluency of test stimuli was induced by presenting words in mixed lists with nonwords (e.g., HENSION) and pseudohomophones (e.g., PHRAWG), and participants gave more "old" responses to pseudohomophones compared to both words and nonwords. Whittlesea and Williams concluded that surprising or unexpected fluency for an item, task or context (in that particular case, for pseudohomphones compared to novel words and nonwords) is attributed to prior exposure in the context of a recognition memory test, but that, depending on the experimental context, familiarity of the stimulus is only one of the outcomes that surprising fluency can lead to. Although mainly based on findings showing fluency misattributions to memory, Whittlesea and Williams (2000; 2001a; 2001b) proposed the discrepancy-attribution hypothesis. This provides a framework to explain the illusion of familiarity participants experience when processing test cues more or less fluently than expected for the given context. Bastin et al.'s (2019) new integrative model of memory proposes a similar framework where the content of memory is stored in a so-called *core system*, and the task context establishes an attribution system which has the role to interpret the content reactivation signal (or other signals, e.g., fluency stemming from other sources) into a subjective experience. In this model, in the context of fluency attribution to familiarity-based memory, the attribution system is conceptualised as a collection of metacognitive and memory monitoring operations likely associated with prefrontal regions (e.g., DLPFC, Henson et al., 1999), which receives input from the perirhinal cortex, as part of the *entity representation core system*.

1.9. In search of a neural architecture for fluency attribution to memory

Fluency attribution to memory has been studied using electroencephalography (EEG) and functional magnetic resonance imaging (fMRI), in an attempt to understand the mechanism underlying this process. While fMRI offers good spatial resolution about *where* the activity is in the brain, event-related potentials (ERPs) can be used to measure and separate between neural signals associated with processes occurring in close temporal proximity.

The P2 component is a commonly reported evoked visual response peaking at around 200ms following target onset, at anterior-central sites (Luck, 2005). ERP research investigating masked repetition priming (not in a recognition memory paradigm) has found a more positive going amplitude of the P2 component for primed versus unprimed stimuli, particularly when the prime and target were in close temporal proximity (Misra & Holcomb, 2003). Similarly, recognition memory research using ERPs to investigate priming effects found more positive-going amplitudes of P2-like components for primed versus unprimed trials in early time windows: 100-200ms (Li et al., 2017; Wang et al., 2020), and 150-250ms (Woollams et al., 2008). Given its early latency and visual perceptual origins, P2 enhancement for masked repetition priming is likely due to automatic processing of the prime.

The N400 component is a negative going ERP component, peaking between 200-600ms, at centro-parietal sites (Kutas & Federmeier, 2011). Its involvement in repetition and semantic priming is well-documented, research consistently finding attenuated N400 negativity for primed versus unprimed stimuli (e.g., Li et al., 2020; Misra & Holcomb, 2003; see Kutas & Federmeir, 2011 for a review). When using repetition priming in recognition memory tasks, studies also reported an ERP priming effect reflected in an attenuation of the N400 component between 250-500ms (Park & Donaldson, 2016), 300-400ms (Lucas et al., 2012), 300-500ms (Kurilla & Gonsalves, 2012; Li et al., 2017; Woollams et al., 2008), 300-550ms (Wolk et al., 2004). Importantly, N400-related ERP priming effects were reported in centro-posterior electrode clusters, having a qualitatively different topography than the more frontal FN400 old/new effect (Li et al., 2017; Lucas et al., 2012; Wang et al., 2015; Woollams et al., 2008). The FN400 component is a frontally-distributed old/new effect found in recognition memory research, usually associated with familiarity (Rugg & Curran, 2007). There has been some debate about whether FN400 reflects familiarity or simply conceptual priming due to prior exposure to a stimulus, and thus, whether it can actually be functionally dissociated from the N400 component (Voss & Federmeier, 2011). Bridger et al. (2012) found evidence for a topographical and functional difference between the two components, N400 being associated with semantic priming (at study) and having a central distribution and FN400 reflecting an old/new effect (at test) and having a frontal topographical distribution, different than N400. In their recent review, Mecklinger and Bader (2020) concluded that mere implicit conceptual priming cannot account for the differences observed in FN400, although this frontal old/new effect might reflect conceptual priming underlying prior exposure.

ERP priming effects have been reported even in the absence of behavioural priming effects on recognition memory (e.g., Kurilla & Gonsalves, 2012), and also these effects have been found when fluency was manipulated in the study phase (e.g., Li et al., 2020). This suggests that a difference in the ERP amplitudes for fluent versus non-fluent stimuli might not capture the attribution process to memory, but rather a source of fluency, especially in early time windows. There are two interesting reports of ERP priming effects from 1200-1600ms with a frontal distribution, stronger in the right electrodes than left (although not significantly stronger) (Wolk et al., 2004) and from 500-700ms, stronger in a group not expected to attribute fluency to memory (i.e., who studied the words in an auditory modality) (Kurilla & Gonsalves, 2012). While centro-posterior priming effects in earlier time windows might indicate perception of fluency per se, these later effects might hint to a frontal source of the attributional process of fluency to memory.

Evidence from fMRI studies provide some insight into underlying sources of fluency attribution to memory. The role of the perirhinal cortex (PRC) in recognition memory was explored in the context of fluency attributions to memory (Dew & Cabeza, 2013). They found a decrease in PRC activity for primed versus unprimed stimuli that were not presented at study. Connectivity analyses showed increased connectivity between PRC and right lateral prefrontal cortex, and between PRC activity and left cuneus activity in the visual cortex for primed versus unprimed stimuli (Dew & Cabeza, 2013). Similarly, Gomes, Mecklinger and Zimmer (2019) found increased connectivity between the BA35 subregion of the PRC and the (pre)cuneus for primed versus unprimed trials overall. Also, in their review, Henson and Fletcher (2001) highlighted the role of right dorsolateral prefrontal cortex in retrieval monitoring. Thus, connecting these findings with the ERP priming effects reported in late time windows with a frontal distribution (e.g., Kurilla & Gonsalves, 2012; Wolk et al., 2004), it can be suggested that fluency attribution to memory might be associated with the connectivity between PRC and right prefrontal regions.

1.10. Short-term masked priming and recollection

As mentioned in a previous section of this review, it is important to consider the specific nature of the semantic relationship between prime-target pairs used in conceptual priming studies. In the case of word pairs with high free association rates showing participants one of the words is very likely to bring to their mind the other word of the pair and this effect is minimally influenced by context (Nelson et al., 2000). When being prompted to indicate whether they remember a given word in the test stage of a memory task, participants are required to actually indicate whether they have encountered it in the study list (which can be considered a context) and not whether they remember the word itself which is very likely they easily do (Montaldi & Mayes, 2010). Thus, it can be argued that when conceptual priming experiments use prime-target pairs with high free association rates, related primes increase conceptual fluency of target words regardless of whether the words have been presented in the study list or not. Results of the studies described previously (i.e., Dew & Cabeza, 2013; Rajaram & Geraci, 2000) provide support for conceptual fluency attribution to memory; in these studies, increasing conceptual fluency of test items through associative primes determined an increased rate of 'old' responses for primed versus unprimed words regardless of the study status.

Using masked conceptual priming, Taylor and Henson (2012) found an increased rate of R but not of K responses for studied words, suggesting that when conceptually related primes are not lexically associated with the target words, they can increase correct recollection. The authors explain these findings within a 'partial recollection' framework, arguing that activation of conceptually related primes in combination with the target words may improve participants' ability to retrieve the episodic memory trace they created in the encoding phase, prime-target pairs acting like better retrieval cues than the target words alone. These results were replicated in an fMRI experiment using a similar design, masked conceptual priming increasing the rate of R responses for studied items only (Taylor et al., 2013). In support of the influence of conceptual primes on recollection as reflected by R responses, an fMRI analysis on regions of interest (ROIs) associated with recollection (determined by the contrast R hits > K hits) showed that conceptual priming modulated activity in bilateral inferior parietal cortices and, only marginally, in posterior cingulate cortex (Taylor et al., 2013). Furthermore, across participants the behavioural priming effect on R responses was positively correlated with the neural modulation effect conceptual priming had on ROIs associated with recollection. Using two-character Chinese words and the same procedure as Taylor et al., Li et al. (2017) replicated the conceptual priming effect on recollection hits only.

It is necessary to mention, however, that the effect of conceptual priming on recollection-based judgments has been observed when using both masked conceptual priming and masked repetition priming within the same experiment with a blocked design. As mentioned in the previous section, repetition priming had a selective effect on K responses increasing their rate for both studied and unstudied words, but had no effect on R responses. In contrast, conceptual priming affected R responses for studied words only, but had no effect on K responses. When Taylor and Henson (2012) used only masked conceptual priming in a subsequent experiment, no significant effects were found on either K or R responses. Recently, Wang et al. (2015) employed a similar procedure in an EEG experiment using masked conceptual priming of test items in an R/K paradigm. Although they did not include repetition priming in the experimental design, they found that conceptually related primes briefly flashed before target words increased R responses rates for studied words only. In addition, they found a positive correlation between the behavioural effect of conceptual priming on R responses and the modulation of ERP amplitudes associated with R hits in the 300-500 ms time window. Across participants, the rate of R hits in the primed minus unprimed trials (i.e. the behavioural measure of conceptual priming) correlated with differences in ERP amplitudes for primed (more positive) versus unprimed R hits averaged across the 300-500ms time window at three electrode clusters (frontal, central, and parietal). This result provides some evidence for the link between conceptual priming and recollection.

In addition, Wang et al. (2015) also found a conceptual priming effect on K FAs which they linked with a (conceptual) fluency attribution account of memory. However, the differences in the patterns of results between their study and the previously described ones could be due to several factors such as the stimuli used (i.e., Chinese words in Wang et al. versus English words in Taylor & Henson) or the version of the R/K paradigm (R/K/New judgments versus old/new judgments followed by R/K judgments for ‘old’ responses), the context of test lists (conceptual priming only versus conceptual priming and repetition priming). Although beyond the scope of this project, further research should aim to clarify these differences in results by exploring context list- and paradigm-related influences on conceptual priming effects on memory judgments. Nonetheless, it could be argued that Wang et al.’s (2015) behavioural and ERP findings brought further evidence for the ‘partial recollection’ effect of conceptual priming.

1.10.1 Potential explanations for the conceptual priming effects on recollection

The ‘partial recollection’ hypothesis is supported by models highlighting the importance of study-test context match for remembering. The encoding specificity principle proposed by Tulving and Thomson (1973) claims that both the encoding content and context are important for subsequent memory performance and retrieval cues during test can only be effective if they are related to the specific encoding context. For example, Light and Carter-Sobell (1970) biased the meaning of nouns presented in the study list using adjectives (e.g., the meaning of the target noun ‘jam’ could have been biased by preceding it by ‘strawberry’ or ‘traffic’). In the subsequent recognition test participants were more accurate for studied items when the encoding context matched the test context (e.g., if in the encoding they studied ‘strawberry jam’, they were more likely to endorse ‘strawberry jam’ or ‘raspberry jam’ as ‘old’ than ‘traffic jam’). Similarly, the transfer appropriate processing theory (Morris, Bransford & Franks, 1977) proposes that memory success depends on the match between what is learnt and what is being tested. Considering these theories and the fact that subliminal primes are processed at the semantic level, as concluded by Van den Bussche, Van den Noortgate and Reynvoet (2009) in their meta-analysis, it can be proposed that conceptual primes (partially) trigger the episodic memory trace acting like a retrieval cue in combination with the actual target word. Presumably, the effect of conceptual priming is context-dependent on the spontaneous thoughts generated by participants in the encoding rather than being explained in terms of conceptual fluency attributions to memory which would involve increases in both Hits and FAs, independently from the study context.

1.11. Item fluency account versus encoding context reactivation account

Considering all these findings together, it is tempting to suggest that the mechanisms by which masked priming affects recognition memory cannot simply be explained through fluency attribution to prior exposure. We propose a distinction between an item fluency account and an encoding context reactivation account. (1) The *item fluency account* seems to be supported by a mechanism where manipulating the perceptual or conceptual fluency of a test item can increase participants’ likelihood to endorse it as studied, in specific task conditions as expanded on in the previous sections. Importantly, the fact that fluency induced through different experimental manipulations is often misattributed to prior exposure (i.e., unstudied items being endorsed as studied when they are processed more fluently than other items in the test list), suggests that the item fluency account works independently from the encoded memory trace of the item and it relies more on participants' learnt bias that fluently processed items are likely encountered in the past. This is also supported by consistent findings that increasing item fluency affects familiarity-based memory that relies on a *feeling of knowing* and not recollection where retrieval of the encoded memory trace is important. (2) On the other hand, we interpret conceptual priming effects on recollection through an *encoding context reactivation account*. We do not reject the assumptions that conceptual primes (even when they are not lexically associated with the target) can increase the fluency of the target they precede. However, we feel that the effects of conceptual primes on recollection can only be explained through a different mechanism than fluency attribution to prior exposure. Rather than "pre-activating" the target (i.e., increasing item fluency), we propose that non-associative conceptual primes act as retrieval cues along with the target, which will actually help participants access the encoded memory trace. Ratcliff and McKoon (1988) proposed a theory of priming on recognition memory, whereby the prime and the target combine and form a compound cue that is then used to access encoded memory traces. This aligns with the mechanism we propose for conceptual priming effects on recollection.

1.12. Aims and objectives of the thesis

The thesis will investigate the effects of short-term masked priming on recognition memory, following two branches: repetition priming effects and conceptual priming effects on familiarity and recollection, respectively. Repetition priming effects on recognition memory and, familiarity, in particular, will be studied in the framework of fluency attribution to prior exposure. Although previous research has isolated event-related potential differences and brain regions associated with priming during recognition memory tests (e.g., Lucas et al., 2012; Li et al., 2017; Woollams et al., 2008), it is still not clear what the neural mechanisms underlying fluency attribution to memory are. Using fMRI, Dew and Cabeza (2013) and Gomes et al. (2019) found increased connectivity between the perirhinal cortex and right lateral prefrontal cortex for primed versus unprimed trials; however, it remains to be elucidated how the neural system involved in the process of fluency attribution to memory can be switched on/off when fluency is/is not relevant for memory decisions. We investigated how study-test modality (mis)match modulates behavioural repetition priming effects on recognition memory (Chapters 2 and 3) and the effective connectivity between brain regions involved in fluency attribution to memory (Chapter 3).

Conceptual priming effects on recognition memory and, recollection, in particular, will be studied within the proposed framework of encoding context reactivation. The *encoding context reactivation account* is currently supported by studies that found an increase in correct recollection by using non-associative conceptual priming (Li et al., 2017; Taylor & Henson, 2012; Taylor et al., 2013; Wang et al., 2015). The proposed explanation for these findings indicates that conceptual primes form a compound cue with the target word they precede, and this is working as a better retrieval cue for the encoded memory trace than the target alone. This explanation relies on the assumption that the prime-target compound reactivates the encoded context (i.e., the spontaneously generated concepts at study); however, this is merely speculative, since the encoded context has not been controlled in these studies, participants freely making interestingness judgments about the target words at study. Secondly, the lack of increase in false alarms due to conceptual priming led to the assumption that the item fluency account cannot explain the priming effects. On one hand, the fact that non-associative conceptual primes did not increase familiarity for either studied or unstudied words supports the rejection of the item fluency account; on the other hand, these results do not completely reject item fluency attribution to recollection solely on the basis of a lack of priming effects on false alarms, because it is not often that participants make recollection false alarms in such experimental setups. Therefore, Chapter 4 of the thesis is addressing these, by (1) controlling for the encoded context of target words and (2) using conceptual primes related to the target they preceded, but either also related to the encoded context or related to a different context.

Chapters 2 and 3 will focus on fluency attribution to memory and how study-test modality (mis)match influences the behavioural priming effects (both experiments) and the neural priming effects (Chapter 3 experiment). Chapter 4 consists of a series of 4 experiments to investigate conceptual priming effects on recognition memory, controlling for the encoded context (Experiment 1) or for the encoded meaning of target homonyms (Experiments 2-4) and then using primes related to the encoded context/meaning, related to a different context/meaning and unrelated. The objective of Chapter 4 is to find support for the *encoded context reactivation account* by showing that only primes related to the encoded context/meaning of the target words will increase recollection.

Chapter 2: Attribution of fluency to memory: Effects of study-test modality (mis)match and study list context

Abstract

Memory judgments can be influenced through briefly preceding the target stimuli with their own masked presentation during the test phase of recognition memory tasks. Such masked repetition priming has been shown to increase the proportions of "old" responses for both studied and unstudied words. Studies that distinguish between familiarity and recollection judgments have found that repetition priming increases familiarity, rather than recollection, for both studied and unstudied items. The generally accepted explanation for this phenomenon is that repetition priming increases the speed of processing of primed words compared to unprimed words, and this perceptual cue (i.e., fluency) is used as evidence for prior exposure; more simply put, processing fluency induced by repetition priming is (mis)attributed to memory. However, the mere increase in processing fluency is not enough to trigger the attribution process; participants need to perceive fluency as a useful cue for prior exposure. In the present study which employed a visual R/K test, participants studied words either visually (V), auditorily (A) or both (intermixed A/V) and during the memory test we used masked repetition priming. Results showed that primed words were responded to (old/new) faster than the unprimed words in all three groups, regardless of the study modality. However, only when there was 100% (V) or 50% (A/V) modality match between study and test did participants show repetition priming on the proportion of familiarity responses for both studied and unstudied words. This pattern of results was in the predicted direction and suggests that the study list context as well as the study-test modality (mis)match modulate fluency attribution to memory.

2.2. Introduction

There is a growing body of research investigating the use of fluency as a heuristic for memory decisions. Familiarity, conceptualised as the feeling that something experienced in the present has been encountered in the past, may result from different types of signals: memory-based, originating from the match between a current stimulus and its stored representation (Clark & Gronlund, 1996); and fluency-based, arising from the ease of processing of a current stimulus (e.g., Rajaram, 1993). Based on the experience that stimuli we have been exposed to in the past are processed faster than new stimuli, fluency became a heuristic for recognition memory. Thus, during a recognition memory task, if a stimulus is processed faster than others, it is likely that its perceived fluency will be attributed to prior exposure.

In a recently proposed model of memory, Bastin et al. (2019) claim that the subjective experience participants have during a recognition memory task arises from an interaction between core systems, which store representations of previously encountered stimuli, and an attribution system. According to this model, when making familiarity decisions, for instance, the fluency signal participants might perceive is processed within a broader metacognitive context and, depending on the specific circumstances in which they experience it, they might attribute fluency to memory or not. Empirical studies support an attributional process operating somewhere between perceptual cues associated with the processing of an item (e.g., its processing fluency) and recognition memory decisions. When processing fluency is induced experimentally, it is often attributed to prior exposure, but only when participants are naïve about the real source of fluency (e.g., Jacoby & Whitehouse, 1989) and when visual fluency can be considered relevant for prior exposure (e.g., Westerman, Lloyd & Miller, 2002), as will be detailed further below.

Various procedures have been used to induce fluency experimentally, such as increasing the clarity of targets (e.g., Willems & Van der Linden, 2006), or briefly preceding targets by their own masked presentation (e.g., Jacoby & Whitehouse, 1989). In the present experiment we used the latter, masked repetition priming method, which involves briefly presenting a word, referred to as *prime*, before the target words of a test list in a memory task. The prime can be matching the target (‘primed’ condition) or non-matching (‘unprimed’ condition). Research using masked repetition priming of target stimuli during recognition memory tests has found increases in the proportion of “old” responses (Jacoby &

Whitehouse, 1989) or "familiar" responses (Rajaram, 1993; Taylor & Henson, 2012; Woollams et al., 2008) for primed versus unprimed words. Since it has first been reported by Jacoby and Whitehouse (1989), the repetition priming effect on recognition memory has become well established through multiple replications (e.g., Bernstein & Welch, 1991; Huber et al., 2008; Joordens & Merikle, 1992; Taylor & Henson, 2012; Li et al., 2017). The currently accepted explanation for this effect is fluency (mis)attribution to memory – when participants are unaware of the experimental manipulation, faster processing of the primed words is attributed to prior exposure. When participants are aware of the primes, the priming effect on recognition memory disappears (Jacoby & Whitehouse, 1989), potentially due to the fact that they are able to correctly attribute the fluency to its actual source (i.e., the (visible) primes). This suggests that the attribution mechanism can be switched on or off depending on the broader context.

The engagement of the attribution mechanism seems to be modulated by participants' expectations and perceived relevance of the fluency heuristic for recognition memory decisions. Because it allows the researcher to keep the experience of the test phase exactly the same across groups, a well-controlled method to investigate the mechanism by which fluency is (mis)attributed to memory is to manipulate the modality match between study and test lists. Westerman et al. (2002) investigated the effect of study-test modality mismatch on repetition priming and found that when participants study the words auditorily and are then tested visually, the repetition priming effects on recognition memory are significantly diminished. This has been replicated by Miller, Lloyd and Westerman (2008) even when participants were required to visualise the words while hearing them in the study phase. In addition, the perceptual match between study and test seems to modulate the priming effects on recognition memory even within-modality (Westerman, Miller & Lloyd, 2003), with significantly larger priming effects when the words are studied in the same font as they are presented in the test list compared to a (dramatically) different font. It appears that a mismatch between study and test renders experimentally-induced fluency of test items irrelevant for memory judgments.

A more recent study aimed to investigate the influence of study-test modality (mis)match on the magnitude of the repetition priming effect on recognition memory using a longer study list (~200 words; cf. ~60 words in a single list in studies by Westerman and colleagues reviewed above) and, consequently, a long test list (~400 words) (Kurilla & Gonsalves, 2012). There were no repetition priming effects in either of their two groups (i.e., visual study/auditory study), regardless of the study modality. It is not entirely clear what could explain the lack of repetition priming effects in the study-test modality match group; one potential reason could be the long test list which might have made participants more likely to spot the masked primes and therefore discard the fluency induced by them, as proposed by the authors. Another potential reason could be waning attention which makes the primes less effective if participants are not paying enough attention at the start of each trial.

The study-test modality (mis)match manipulation combined with the Jacoby-Whitehouse paradigm is potentially theoretically important because it provides the space to investigate the fluency attribution to memory mechanism in terms of the cues participants find relevant for recognition memory judgments and how these might be influenced by changing the experimental context. Methodologically, manipulating fluency attribution to memory by changing the study modality between groups provides a "clean" way to switch on/off the fluency-attribution-to-memory mechanism. An alternative way used by Jacoby and Whitehouse (1989) to study the attribution mechanism was to manipulate prime awareness between groups by varying the duration of the primes (and by informing participants or not about the primes), which also increased the prime-target SOA in the "aware" group. In contrast, the study-test modality (mis)match manipulation has the advantage of keeping the test phases identical in both attribution-expected and attribution-not-expected conditions. This is particularly desirable for neuroimaging studies using EEG or fMRI, since perceptual differences between conditions are minimised. However, results have been equivocal (Kurilla & Gonsalves, 2012), particularly with large number of trials (another important factor for neuroimaging studies).

The present experiment was designed to replicate the modulatory effects of study-test modality (mis)match and of the study list context on the repetition priming effects on recognition memory. In addition, we investigated whether, in this context, priming selectively affects familiarity or recollection, as measured by the R/K paradigm (Tulving, 1985). Further, we aimed to test whether this pattern of repetition priming effects could be found with longer lists of stimuli (than 60, as included in Westerman and colleagues' studies) which would be necessary for neuroimaging studies (e.g., EEG, fMRI). To achieve this, we used the study-test cycle method that is common in neuroimaging (e.g., Taylor et al., 2013, Woollams et al., 2008).

2.3. Methods

Design. The experiment was conducted as a 3 (study modality: Auditory (A), Visual (V), or Auditory/Visual (A/V)) x 2 (prime type: matching or mismatching word) x 2 (study status: studied or unstudied) mixed factorial design, with prime type and study status as within-participants factors and study modality as between-participants factor. The dependent variables were the proportions of 'old', 'familiar', and 'remember' responses, and median response times for 'old'/'new' responses in each condition.

Participants. Fifty participants were randomly allocated to the Auditory study or the Auditory/Visual study groups. Data were subsequently collected from 29 participants allocated to the Visual study group. Due to a technical error, responses from one participant in the Visual group were not recorded. Participants were excluded from further analysis if their overall memory performance (calculated as Hits – False Alarms) was below 2.5 standard deviations lower than the mean (<15%; 2 participants) or if they made many recollection false alarms (>4%; 6 participants). Participants do not generally make many recollection false alarms in the R/K paradigm as used in the present study; across the experiment, the median of recollection false alarms was 1, with 31 participants not making any recollection false alarms (see Supplementary materials). The interquartile range (IQR = quartile 3 – quartile 1) was calculated and participants who made more than Q3 (quartile 3) + 1.5*IQR recollection false alarms were excluded. Analyses are reported on 23 participants in the auditory group (mean age = 22.35, SD = 4.45 years, 17 female), 24 participants in the visual group (mean age = 19.25, SD = 0.79 years, 23 female), and 23 participants in the auditory/visual group (mean age = 22.13, SD = 3.84 years, 14 female). All participants were students at the University of Manchester and reported to be in good neurological health with normal or corrected-to-normal vision and hearing. They were tested individually in a testing cubicle and received either Psychology course credits or financial compensation for their participation. The sample size of roughly 24 participants per group provided a power of 0.8 to detect a medium-sized effect of priming in a repeated measures design with two levels (i.e., a Cohen's d equal to 0.55).

Stimuli. The stimuli of interest consisted of 480 words used as targets and 480 words used as mismatching primes (see Supplementary materials), taken from the stimulus set used in Taylor & Henson (2012). All stimuli were between 3 and 9 letters long (targets: M = 5.66, SD = 1.36; primes: M = 5.21, SD = 1.19) and had written frequencies between 1 and 150 per million (targets: M = 33.65, SD = 35.09; primes: M = 30.27, SD = 26.38, based on CELEX, Medler & Binder, 2005). The words used as targets cycled through conditions (auditory study/visual study/unstudied) across participants. Stimuli were divided into 32 lists of 15 word pairs. Within each list, the matching primes were the same as the target words and the mismatching primes were always new words sampled from the mismatching primes list. In addition to the stimuli of interest, there were 172 fillers having similar word length and written frequencies as the stimuli of interest, used in non-critical conditions (detailed in procedure below; grey boxes in Figure 2.1).

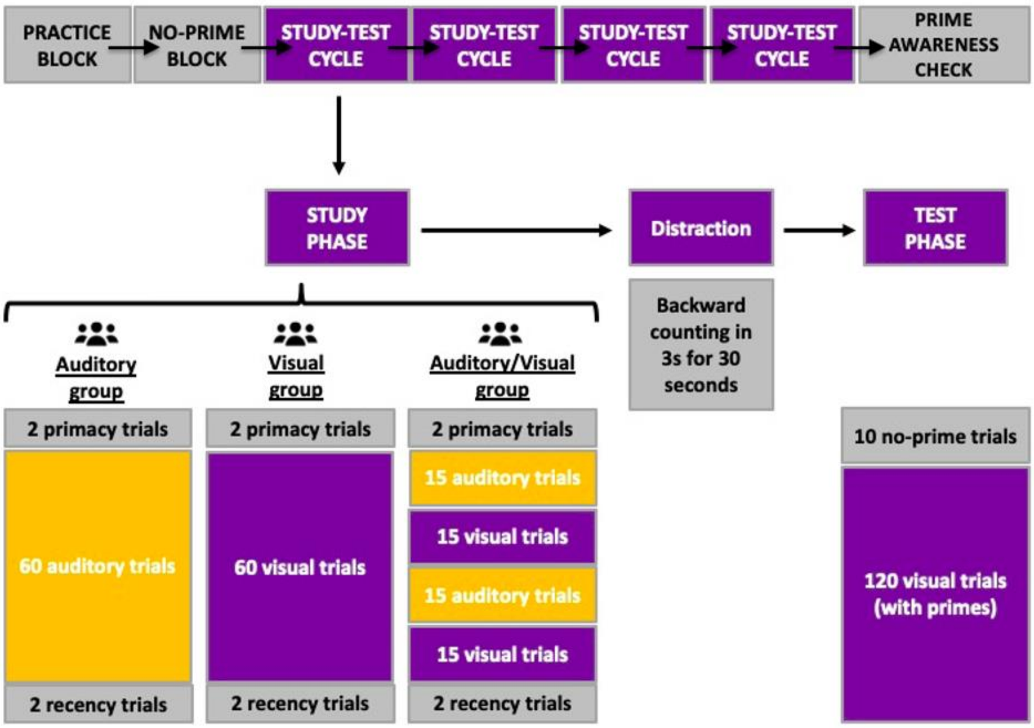


Figure 2.1. Schematic illustration of the structure of the experiment. Top row: session procedure (left-to-right); bottom: one study-test cycle expanded to show study phase (different for the 3 groups), distraction task, and test phase (same for all 3 groups). Colours shown here are only for illustrative purposes; the screen was grey for all trials.

Validation of the auditory stimuli. The auditory stimuli were generated using Apple voice synthesizer (British accent, Daniel, at a frequency of 200 wpm) (see Supplementary materials for the code used to generate the words). Both the targets and the primes used in Taylor and Henson were generated. To ensure the intelligibility of the machine-generated speech, three British English native speakers listened to the words and were required to write each of them down. We excluded words that could not be understood (i.e., at least one of the three raters indicated they were not intelligible), that did not sound natural enough (i.e., at least one of the three participants indicated this), that were homophones (i.e., at least one of the three participants produced a different written form than what was intended). In the cases where the words used as targets in Taylor and Henson failed this validation test, they were instead used as primes (all primes were presented visually) and were swapped with primes from Taylor and Henson that did pass the validation test, which then became targets. Details about word length and frequency of stimuli presented above apply to the final set of validated stimuli.

Procedure. The experiment consisted of a short practice block, 1 no-prime block (60 words presented in the study phase and 120 words (half studied and half unstudied) presented in the test phase); 4 study-test cycles of interest; and a short prime awareness check. Stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). The inclusion of an initial no-prime block had the purpose of enhancing the salience of fluency induced by priming in subsequent blocks. During encoding, the Auditory group studied all words auditorily in headphones; the Visual group studied all words visually; the Auditory/Visual group studied half of the words visually and half of the words auditorily (15V + 15A + 15V + 15A). The order of sub-lists (AVAV or VAVA) was counterbalanced across participants in the Auditory/Visual group. The test list consisted of 10 initial trials that were not preceded by primes + 120 target words (60 studied and 60 unstudied). Regardless of the study modality, all three groups received a visual memory test (see Figure 2.1). In the study phase, participants had to indicate if they found the words interesting or not by button press (see top Figure 2.2). In order to test participants' memory for the studied words, we used a modified version of the R/K paradigm (Tulving, 1985) in which we replaced 'know' with 'familiar' (as in Taylor & Henson, 2012; see Figure 2.2). During the test phase, participants first indicated whether the word was presented in the study phase ('old') or not ('new'); for words judged as old, they further indicated whether they 'remember' the word or it was just 'familiar'. Participants responded using their index and middle fingers of the dominant hand. In line with the name of the original version of the paradigm, throughout the paper, 'familiar' responses will be referred to as K and 'remember' responses as R. Participants were told to respond as accurately as possible within the 2s time limit (responses made after the time limit were not recorded and the trials considered invalid).

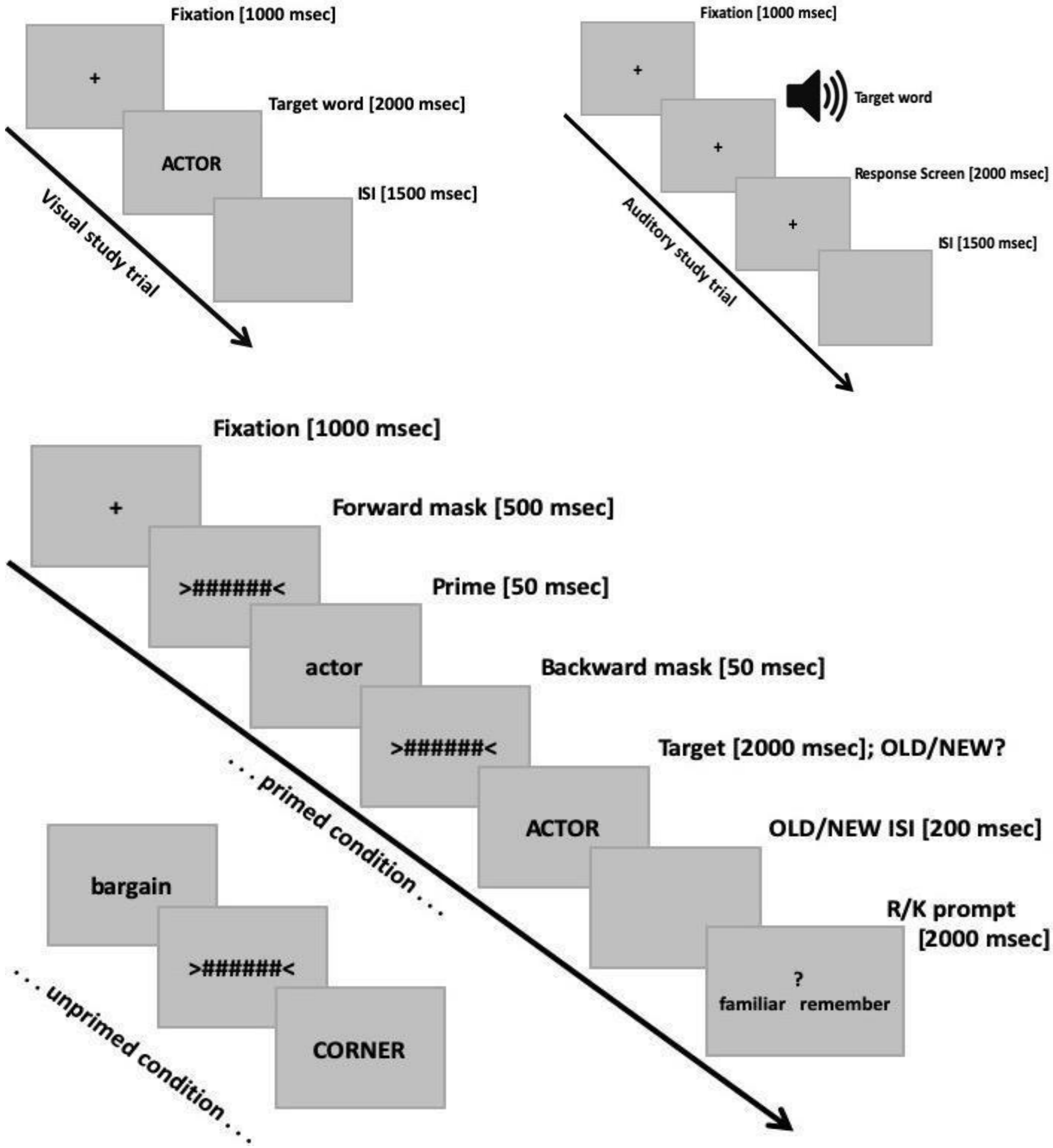


Figure 2.2. Schematic representation of trials during the study phase (top) and during the test phase (bottom) of the experiment.

All three groups completed a short practice block to familiarise themselves with the tasks. The experimenter briefly explained the experiment (see Supplementary materials), then participants completed a short practice block consisting of a short study list, the distracting task and a short test list. After this, the experimenter checked whether participants understood the difference between 'familiar' and 'remember' options (i.e., familiarity/recollection). Depending on their responses, the instructions were given again with a tailored amount of details. Once this distinction was clear for participants, they started the actual experiment and completed 5 blocks[1], having the option to take breaks in-between them if needed.

Following the completion of the experiment, participants were asked *whether they noticed anything unexpected during the experiment*. If they responded with nothing or if something other than the presence of masked primes was reported, the experimenter asked whether they noticed the hidden words preceding the targets in the test phases. Participants' responses were coded as follows: 1 – unaware, 2 – aware of something being flashed but not able to read the prime words, 3 – aware of the prime words, 4 – aware of the prime words and aware that sometimes they were the same as the target words they preceded.

Statistical analyses

Proportions of responses. In order to replicate previous research (Westerman et al., 2002), first, a 3 (group: auditory, visual, auditory/visual) x 2 (priming: primed, unprimed) x 2 (study status: studied, unstudied) ANOVA was performed on "old" responses. An interaction was expected between group x priming, with priming effects (more 'old' responses for primed than for unprimed trials) in the visual and auditory/visual groups, but not in the auditory group. The prediction of the present experiment is that priming would affect K responses, but not R responses. To check this, a 3 (group) x 2 (priming) x 2 (study status) ANOVA was performed on the proportions of K responses. An interaction was expected between group x priming, with priming effects (i.e., higher proportions of K responses for primed versus unprimed words) in the visual and auditory/visual groups, but not in the auditory group. Although we did not have strong predictions about its interaction with priming, study status was added as a factor, given that previous research found priming effects either on both K hits and K false alarms (Rajaram, 1993; Taylor & Henson, 2012; Woollams et al., 2008) or on K false alarms only (Taylor et al., 2013). In addition to this main analysis of interest, a 3 (group) x 2 (priming) ANOVA was separately performed on proportions of R hits, with no significant priming effects expected in any of the three groups. Study status was not added as a factor in this analysis given that participants made very few R false alarms (see Supplementary materials).

[1] Because of a technical error with one of the lists used, 1 block had to be excluded (in which the list appeared) from each participant's data which resulted in 360 critical trials instead of 480.

Response times. A 3 (group) x 2 (priming) ANOVA was performed on median response times (RTs) associated with K Hits (i.e., RTs to the first old/new judgment followed by "familiar" responses). Due to insufficient number of trials (<10/condition in the majority of participants), median RTs for K false alarms were not calculated, and study status not included as factor in the ANOVA. Separately, median RTs associated with R Hits were extracted for primed and unprimed words and a 3 (group) x 2 (priming) ANOVA was performed. Previous studies reported faster RTs for primed versus unprimed words in a memory task (e.g., Jacoby & Whitehouse, 1989; Taylor et al., 2012; Woollams et al., 2008). Although we did not emphasise RTs and asked participants to try to be as accurate as possible (within the 2s time limit), rather than fast, it was expected that RTs for primed words will be faster than RTs for unprimed words for both K and R responses, regardless of the group.

Exploratory analyses. In order to test for differences in priming effects on familiarity and recollection as a function of group, priming scores were calculated as Primed – Unprimed trials (raw proportions could not be used since familiarity and recollection were not measured independently), and a 3 (group) x 2 (response: familiarity, recollection) ANOVA was performed. In addition, to investigate whether the priming effects in the A/V group were influenced by the items' study modality when this was manipulated within-group, three separate 2 (within-A/V group study modality) by 2 (priming) were performed on hits overall, K hits and R hits in the Auditory/Visual group only; note that in this case study modality is different from group. All analyses performed on K responses were also conducted on familiarity responses calculated under independence assumptions as iK=K/(1-R) (Yonelinas & Jacoby, 1995)) and they are reported in the Supplementary Materials section at the end of the paper. Finally, the main analyses (mentioned in the "Proportions of responses" sub-section) were repeated for a sub-sample of participants who were not aware of the primes (i.e., whose responses on the question about *hidden words* was coded as 1 or 2). A .05 significance threshold was used when interpreting the results of all analyses. T-tests were two-tailed, unless specifically reported otherwise.

2.4. Results

As an initial check, we compared memory performance (Hits – False Alarms) across the three groups and for R responses and K responses separately. Results showed that all three groups had similar memory performance (see Table 2.1). A one-way ANOVA did not show a significant main effect of group on memory performance (F(2,67) = 2.60, p = .081). Memory performance was above chance for both K responses (t(1,69) = 9.34, p < .001) and R responses (t(1,69) = 18.73, p < .001).

Table 2.1.
Memory performance calculated as Hits – False Alarms for each group: overall, and for K and R responses separately. Standard deviations shown in parantheses.

Auditory study group			Visual study group			Auditory/Visual study group		
Hits – FAs			Hits – FAs			Hits – FAs		
Overall	K	R	Overall	K	R	Overall	K	R
0.67 (0.14)	0.20 (0.16)	0.47 (0.20)	0.56 (0.20)	0.19 (0.15)	0.37 (0.18)	0.59 (0.19)	0.16 (0.18)	0.44 (0.18)

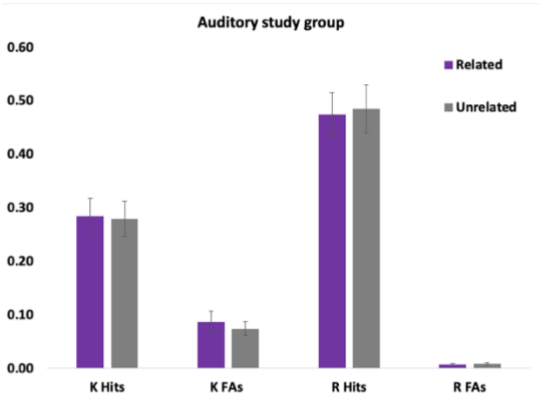
Proportions of responses. Mean proportions of responses for each condition are presented in Table 2.2 and Figure 2.3. The 3 x 2 x 2 (group by priming by study status) ANOVA on "old" responses showed a main effect of study status (simply indicating that participants made more "old" responses to studied items than to unstudied ones), a main effect of priming (F(1,67) = 10.93, p = .002, partial η^2 = .140) with significantly more "old" responses to primed compared to unprimed words, and a main effect of group (F(2,67) = 4.49, p = .015, partial η^2= .118). Follow-up Bonferroni-corrected post-hoc tests on the main effect of group showed participants in the Visual group made significantly fewer "old" responses than those in the Auditory group (p = .024), and showed no significant difference between the number of "old" responses in the Visual and Auditory/Visual groups (p = .058) or in the Auditory and Auditory/Visual groups (p > .9). Even though the interaction group x priming was not significant (F(2,136) = 1.98, p = .146, partial η^2 = .056), to test for the predicted pattern of priming effects across groups, separate 2 x 2 (priming by study status) ANOVAs were conducted in each group. They showed significant priming effects in the predicted direction in the Visual group (F(1,23) = 7.83, p = .010, partial η^2 = .254) and in the Auditory/Visual group (F(1,22) = 7.10, p = .014, partial η^2 = .244), but not in the Auditory group (F(1,22) = .09, p = .770, partial η^2 = .004). The interactions between study status x priming were not significant in any of the three groups (Visual (F(1,23) = 2.44, p = .132, partial η^2 = .096), Auditory/Visual (F(1,22) = .05, p = 827, partial η^2 = .002), Auditory (F(1,22) = 1,15, p = .296, partial η^2 = .050).

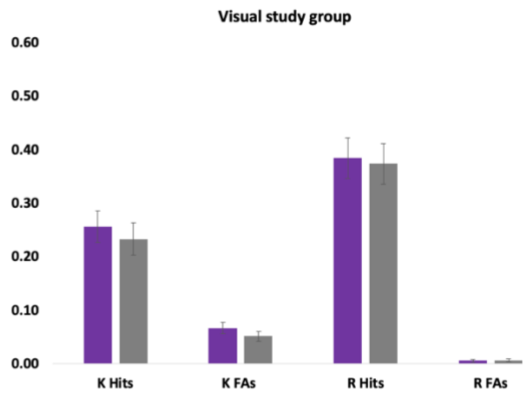
Table 2.2.

Mean proportions of responses to studied and unstudied words in each group

Response	Auditory study group				Visual study group				Auditory/Visual group			
	Studied		Unstudied		Studied		Unstudied		Studied		Unstudied	
	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed
K	0.29 (0.15)	0.28 (0.16)	0.09 (0.09)	0.07 (0.06)	0.26 (0.14)	0.23 (0.15)	0.07 (0.06)	0.05 (0.04)	0.27 (0.16)	0.25 (0.15)	0.12 (0.10)	0.10 (0.08)
R	0.47 (0.20)	0.49 (0.22)	0.01 (0.01)	0.01 (0.01)	0.38 (0.18)	0.37 (0.18)	0.01 (0.01)	0.01 (0.01)	0.46 (0.19)	0.44 (0.18)	0.02 (0.02)	0.01 (0.01)
New	0.24 (0.16)	0.24 (0.15)	0.91 (0.10)	0.92 (0.07)	0.36 (0.19)	0.39 (0.21)	0.93 (0.07)	0.94 (0.05)	0.27 (0.18)	0.30 (0.17)	0.87 (0.12)	0.89 (0.08)

Note. Standard deviations in parentheses. K – "familiar", R – "remember"





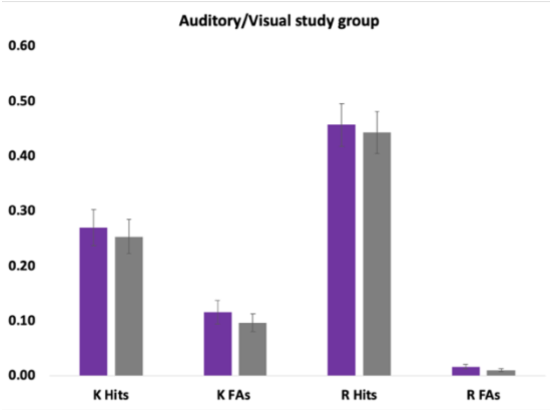


Figure 2.3. Proportions of responses for each condition across groups. Note that recollection false alarms were not analysed (although displayed here), given that participants made very few.

A 3 x 2 x 2 (group by priming by study status) ANOVA on proportions of K responses showed a significant main effect of study status (simply showing that participants made more K responses to studied items than to unstudied ones) and a significant main effect of priming (F(1, 67) = 10.27, p = .002, partial η^2 = .133), with a higher proportion of K responses to primed compared to unprimed words. Although the interaction group x priming was not significant (F(2, 136) = .431, p = .651, partial η^2= .013), in light of the predicted patterns of results, planned contrasts were conducted to look at priming effects in each group. Separate 2 x 2 (priming x study status) ANOVAs were run in each group. In both the Visual group (F(1, 23) = 6.41, p = .019, partial η^2= .218) and the

Auditory/Visual group ($F(1, 22) = 5.31$, $p = .031$, partial $\eta^2 = .194$), there was a significant priming effect in the predicted direction across study status. In the Auditory group, there was no significant main effect of priming ($F(1, 22) = .91$, $p = .351$, partial $\eta^2 = .041$) or significant interaction between priming and study status ($F(1, 22) = .24$, $p = .630$, partial $\eta^2 = .011$). The 3 x 2 (group by priming) ANOVA on R hits did not yield any significant effects.

Exploratory analyses. The 3 x 2 (group by response) ANOVA performed on the priming scores (shown in Figure 2.4) did not show any significant main effects of response ($F(1,67) = .92$, $p = .341$, partial $\eta^2 = .014$) or group ($F(2,67) = 2.35$, $p = .103$, partial $\eta^2 = .066$) and no significant interaction between the two factors ($F(2,67) = .14$, $p = .874$, partial $\eta^2 = .004$).

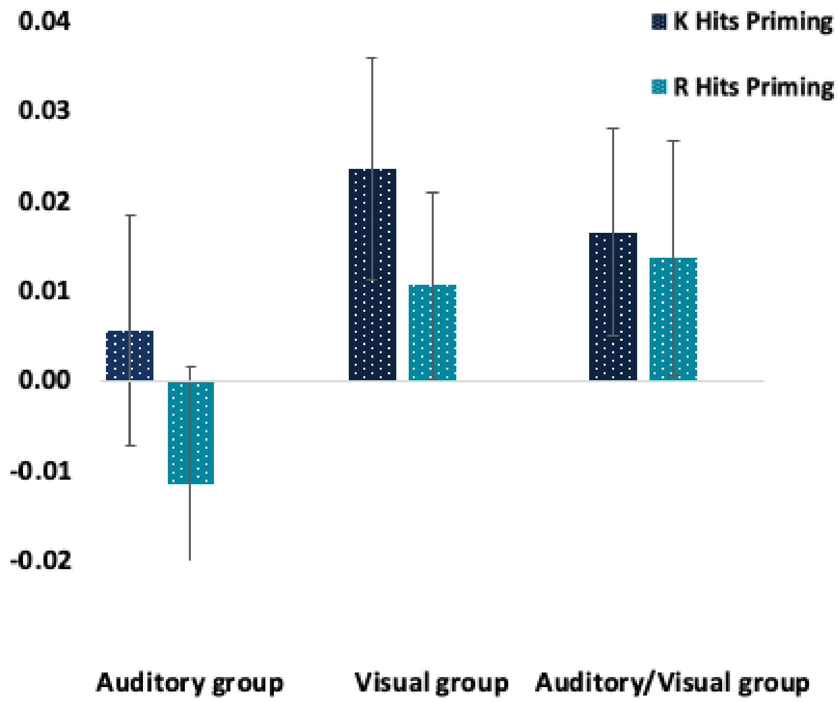


Figure 2.4. Priming effects (calculated as proportions of Primed – Unprimed trials) for the two responses across the three groups. Standard error bars.

When investigating data from the auditory/visual group only, looking at subsequent memory for trials by their study modality, the analysis on hits overall showed a main effect of study modality ($F(1,22) = 11.53$, $p = .003$, partial $\eta^2 = .344$) with more hits for words studied in the visual modality compared to words studied in the auditory modality. There was no significant main effect of priming ($F(1,22) = 3.77$, $p = .065$, partial $\eta^2 = .146$) and no significant interaction study modality x priming ($F(1,22) = 1.11$, $p = .303$, partial η^2 = .048). Something to note is that the nearly significant main effect of priming was in the predicted direction, with more “old” responses to primed targets compared to unprimed ones. The analysis on K hits did not yield any significant main effects of study modality ($F(1,22) = .08$, $p = .775$, partial η^2 = .004) or of priming ($F(1,22) = 2.06$, $p = .165$, partial η^2 = .086) and no significant interaction study modality x priming ($F(1,22) = .24$, $p = .630$, partial η^2 = .011). The analysis on R hits showed a main effect of study modality ($F(1,22) = 6.92$, $p = .015$, partial η^2 = .239), with more ‘remember’ responses given to words studied in the visual modality compared to words studied in the auditory modality, showing a modality-match enhancement of recollection, which is not surprising, and which is orthogonal to the priming effects of interest here. There was no significant main effect of priming ($F(1,22) = 1.08$, $p = .310$, partial η^2 = .047) or significant interaction study modality x priming ($F(1,22)$ = .18, $p = .678$, partial η^2 = .008).

In terms of prime awareness, 42 participants were unaware (12 in the auditory group, 14 in the visual group, 16 in the auditory/study group), 22 participants were only aware of something being briefly flashed (11 in the auditory group, 5 in the visual group, 6 in the auditory/visual group), 4 participants could read some of the words (all in the visual group) and 2 participants were aware that the primes were sometimes the same as the target they preceded (1 in the visual group and 1 in the auditory/visual group). The pattern of results was similar when including the whole sample or a sub-sample of participants who were not aware of the primes (results of the main analyses are reported in Supplementary Materials).

Table 2.3.

Mean of median RT (ms) to studied and unstudied words in each group

Response	Auditory study group				Visual study group				Visual/Auditory group			
	Studied		Unstudied		Studied		Unstudied		Studied		Unstudied	
	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed
K	1007 (189)	1068 (173)	-	-	964 (121)	1003 (112)	-	-	1033 (194)	1054 (191)	-	-
R	845 (127)	875 (110)	-	-	820 (78)	859 (75)	-	-	851 (125)	901 (121)	-	-
New	965 (221)	1019 (236)	903 (150)	908 (142)	863 (151)	850 (154)	825 (101)	833 (101)	952 (166)	970 (183)	918 (137)	894 (132)

Note. Standard deviations in parentheses. K – “familiar”, R – “remember”
– = insufficient trials to estimate RT. The table shows values for the median RTs for “old” responses, subsequently judged as familiar (K) or remembered (R), not the RTs for the familiar/remember judgment itself.

Response times. Means of the median response times are presented in Table 2.3. Two 3 x 2 (group by priming) ANOVAs were performed on median RTs for "old" responses subsequently judged as K and R separately (hits only). There was a significant main effect of priming on K-hit RT ($F(1,67) = 8.71$, $p = .004$, partial $\eta^2 = .115$), but no main effect of group ($F(2,67) = 1.06$, $p = .352$, partial $\eta^2 = .031$) and no significant interaction group x priming ($F(2,136) = .716$, $p = .492$, partial $\eta^2 = .021$). Although the interaction group x priming was not significant, we performed primed versus unprimed contrasts in each group on the K-hit RTs. There were significant priming effects in the visual group ($t(1,23) = 2.500$, $p = .020$) and in the auditory group ($t(1,22) = 2.207$, $p = .038$), but not in the auditory/visual group ($t(1,22) = .776$, $p = .446$). There was also a significant main effect of priming on R-hit RT ($F(1,67) = 34.36$, $p < .001$, partial $\eta^2 = .339$), but no significant main effect of group ($F(2,67) = .73$, $p = .486$, partial $\eta^2 = .021$) and no significant interaction group x priming ($F(2,136) = .72$, $p = .491$, partial $\eta^2 = .021$). Again, although the interaction was not significant, we performed planned contrasts in each group. There were significant priming effects on R-hit RTs in all three groups: visual ($t(1,23) = 3.725$, $p = .001$), auditory ($t(1,22) = 2.531$, $p = .019$), and auditory/visual ($t(1,22) = 3.913$, $p = .001$).

2.5. Discussion

The aim of the study was to investigate item fluency attribution to prior exposure under study-test modality (mis)match conditions, by looking at how the study list context modulates repetition priming effects on recognition memory. Study-test modality match was manipulated between participants, one group studying the words auditorily, one group visually, and one group studying the words both auditorily and visually (intermixed). It was expected that item fluency would be experienced equally across the three groups, but that this fluency would only be attributed to memory in the groups for which there was a (at least partial) match of modality between study and test. Indeed, there was a significant priming effect on response times: primed targets were responded to faster than unprimed targets across groups. Further, participants in the 100% study-test modality match group (i.e., visual study group) and those in the 50% study-test modality match group (i.e., auditory/visual study group), but not those in the study-test modality mismatch group (i.e., auditory study group), showed repetition priming effects on recognition memory, with significantly higher proportions of "old" and K responses to primed versus unprimed words for both studied and unstudied words. These results essentially replicate previous findings by Miller et al., 2008 and Westerman et al., 2002.

Taken together, the patterns of results on proportions of responses and response times indicate that all groups experienced the same level of item fluency perceptually and that group differences occurred at the level of its attribution to memory. When participants studied all words in a different modality than the test list, they were not prone to experience repetition priming effects on recognition memory, so they did not attribute the perceived item fluency to prior exposure. This suggests that item fluency per se is not automatically attributed to prior exposure, but the attribution mechanism can be "switched" on or off depending on whether processing fluency is considered relevant for memory or not; studying the words auditorily renders visual fluency irrelevant for prior exposure. This occurred despite primes being masked and most participants being unaware of them. In addition, when participants studied half of the words in the same modality as the test list (i.e., the Auditory/Visual group), they did use fluency as a relevant cue for prior exposure, regardless of the modality in which they studied the words. This highlights the importance of study list context overall and indicates that once fluency is considered relevant for prior exposure its attribution to memory is not applied at the item level.

The modulation of the repetition priming effects on recognition memory through the experimental context has been acknowledged previously in several studies, apart from the study-test (mis)match modality ones (Westerman and colleagues). Jacoby and Whitehouse (1989) found that being aware of the primes (but also the longer duration of prime presentation) diminishes the repetition priming effect on "old" responses. The proportion of primed versus unprimed words in a test list was found to be inversely proportional with the magnitude of the priming effect on recognition memory (Westerman, 2008). Also, when primed stimuli appear in the same block rather than interleaved with unprimed stimuli within a block, the repetition priming effect of recognition memory disappears when using words (Gomes, Mecklinger & Zimmer, 2017) or images (Wang et al., 2020) as stimuli. It appears that participants unconsciously create a framework of making memory decisions based on the context of the task overall, which includes perceptual (mis)match between study and test, the context of the study list, the way they process test words and which heuristics might be useful in specific contexts.

It seems useful to make a distinction between “pure item fluency”, which we will refer to as non-mnemonic fluency (e.g., when a word is presented in a clearer font than other items, or when a word is read faster than other words in a list), and prior exposure-based fluency, which we will refer to as mnemonic fluency (when a stimulus matches a previously stored representation). The immediate difference between the two types is that the former needs to “pop up” from the environment, so the external context in which it appears matters, whereas the latter is less dependent on the external context in which it is presented and relies more on internal processes. Presumably, when engaged in a recognition memory task and while being unaware of any experimental manipulations of item fluency, it is difficult for participants to disentangle the two. This might be true particularly for the visual study group, when the memory-based fluency might have a similar nature to the item fluency induced by the (visual) experimental manipulation. In the case of the auditory study group, mnemonic fluency leading to “familiar” judgments should arguably be different in nature compared to the non-mnemonic item fluency induced by the visual primes. This might have made it easier for participants to distinguish between the two types of fluency and only use the memory-based type, while discounting the other type, in their recognition memory decisions.

Group differences in terms of recognition memory responses to primed and unprimed words are an indication that not all fluently processed stimuli in a test list will be judged as “old” in any situation. There appears to be a metacognitive process mediating between the mere perception of a stimulus and the memory decision, as suggested by Bastin et al. (2019). For instance, in the case where participants are aware of alternative sources of fluency (e.g., the primes), they will be less likely to experience priming effects on recognition memory as they are able to attribute perceived item fluency to its correct source (e.g., Gellatly, Banton & Woods, 1995; Jacoby & Whitehouse, 1989, Klinger, 2001). In the present study the aforementioned metacognitive process was related to evaluating the relevance of fluency for judgments of prior exposure. This evaluation might be connected to transfer appropriate processing (TAP) (Morris, Bransford & Franks, 1977). Perceived visual fluency did not influence participants in the auditory study group, suggesting that the encoding mechanisms employed during the study phase and the context of the experiment overall made the processing fluency induced by *visual* primes irrelevant for recognition memory decisions. The TAP concept refers to the idea that the nature of the mental processes engaged during encoding could render them useful or not for participants' performance depending on the nature of the memory test. This can explain the lack of priming effects on recognition memory in the study-test modality mismatch group by pointing towards a different set of criteria (e.g., which perceptual cues are relevant) when making recognition memory judgments compared to the study-test modality match groups. However, because there were no differences in terms of priming effects on recognition memory in the auditory/visual group depending on the study modality of the words, it seems that it occurs at a higher level than item-wise.

Methodological considerations. The present study was a conceptual replication of previous research investigating similar hypotheses (Miller et al., 2008; Westerman et al., 2002), adding several new elements: an initial no-prime block, study-test cycles instead of one single study-test list, and participants had to make familiar/remember judgments for every word they considered "old". The inclusion of the initial block with no primes at the beginning of the experiment was a way to enhance the salience of the processing fluency and to increase the magnitude of the priming effect in the subsequent experimental blocks. Westerman (2008) showed that decreasing the proportion of primed trials in a list increases the magnitude of the priming effect on recognition memory. Although we did not follow the same method of decreasing the proportion of primed versus unprimed trials within the test lists, the initial no-primes block was expected to make fluency in subsequent blocks more contrastive. Whittlesea and Williams (2002) proposed the discrepancy-attribution hypothesis according to which the feeling of familiarity results from a lack of coherence in item processing, when expectations created by specific circumstances are in contradiction with the actual processing of the item. They explained that this discrepancy can lead to either a surprising fluency (in their case, reading pseudohomophones when presented in a list of words, participants were able to attach meaning to a seemingly non-word form) or a surprising lack of fluency (in their case, reading non-words that are very similar to word forms, participants not being able to attach meaning to a seemingly word form) which, in the context of a recognition memory task, will be attributed to memory. However, in the present experiment, participants in the auditory study group did not show priming effects on recognition memory despite this intended enhancement of fluency salience; it seems that for repetition priming effects on recognition memory, the relevance of fluency is more important than it being unexpected as suggested by Whittlesea and Williams.

There is no completely objective way to test prime awareness; previously it has been tested either through asking participants to report whether or not they were aware of the primes, or by assessing them more 'objectively' through a prime identification task. However, testing participants' ability to identify the primes involves informing them about the experimental manipulation which renders them more likely to read (or consciously process) the primes (e.g., Taylor & Henson, 2012; Taylor et al., 2013). In the present experiment, we chose to ask for their self-reports on whether *they noticed something unusual during the experiment*. When analysing the sub-sample of participants who were not aware of the presentation of primes, the pattern of results was similar to the one obtained when including the whole sample. Although it was suggested by previous studies (e.g., Jacoby & Whitehouse, 1989) that prime awareness decreases the likelihood of experiencing repetition priming effects, it is not surprising it did not make a difference in the present experiment given the short duration of the primes. Even though they noticed the primes, the majority of participants (except 2) were not aware that some primes were the same as the target word they preceded, so they could not be fully aware of the experimental manipulation and so, did not have a foundation for discarding the fluency of processing as a cue for prior exposure by attributing it to the prime-target match.

Limitations and implications for future work. Apart from the use of an initial no-prime block, the current experiment differed from previous ones by using study-test cycles instead one single study-test list. This allows for more trials to be used without detrimentally affecting memory performance, making the paradigm more suitable for neuroimaging studies. Yet, a potential concern of this method when studying modulatory effects of study modality on memory is that knowing the nature of the memory test would encourage participants to use various strategies that can mask the effects of interest. In this case, participants in the auditory study group could have potentially visualised the words to improve their memory performance because they knew they would receive a visual memory test. Miller et al. (2008) have already investigated whether instructing participants to imagine the visual form of the (auditorily presented) studied words would change the pattern of results in terms of priming on recognition memory in the study-test modality mismatch group (i.e., whether participants who study the words auditorily would experience repetition priming effects). Their findings indicate that even with these instructions, participants in the auditory group do not experience priming effects. Rather than explicitly telling participants to imagine the visual form of the studied words (as Miller et al., 2008), by having study-cycles, the present experiment could have implicitly encouraged participants to visualise the words presented auditorily in the study phase. However, in line with Miller et al.'s results, participants in the auditory study group did not show priming effects. These results replicate findings reported in Westerman et al. (2002) who used one single study/test list. This is important in opening the possibility to study the repetition priming effects using neuroimaging (EEG, fMRI) given that having long single study/test lists might decrease the priming effects even in study-test modality match groups (Kurilla & Gonsalvez, 2012).

Conclusion. The main objective of the experiment was to investigate fluency attribution to memory, focusing on how study-test modality match and the study list context might influence the use of item processing fluency in recognition memory decisions. Similarly with previous studies (Kurilla & Gonsalves, 2012; Miller et al., 2008; Westerman et al., 2002), participants in the present study received a visual memory test and the study list context has been manipulated between-groups. The most important finding of the study is the distinction between priming on proportions of responses and priming on response times across the three groups. While primed words were responded to faster than unprimed words regardless of study modality or response type (K or R), only participants in the visual and the auditory/visual groups (i.e., where there was some level of modality match between study and test presentation), but not participants in the auditory group, experienced priming effects on "old" and K responses. This suggests that the level of item fluency due to priming was similarly experienced by all three groups, but having studied the stimuli in a different modality than the test rendered the fluency cue irrelevant for the memory decision, participants in the auditory study group not attributing it to prior exposure. We can conclude that fluency attribution to memory depends on the study list context, with participants being likely to show repetition priming effects on their "old" and "familiar" responses when there is some extent of perceptual match between the study list and the test list. Using this paradigm, the attribution mechanism can be switched on or off while keeping the test phase identical between conditions, even when study-test cycles are used, making it ideal for adaptation to neuroimaging (EEG, fMRI).

Chapter 3: Attribution of fluency to memory: An ERP and effective connectivity investigation

Abstract

Recognition memory judgments can be influenced by experimentally increasing the fluency of test stimuli through masked repetition priming. Research has consistently reported that test stimuli that are fluently processed are more likely to be endorsed as "old" or "familiar" than non-fluent stimuli in the same test list. The convergent explanation for this phenomenon is that fluency can be (mis)attributed to memory, but the neural mechanisms underlying this attributional process are not fully known. In the present experiment, we investigated how the non-mnemonic fluency attribution to memory can be switched on/off and how this is reflected in the connectivity of the underlying neural system. We used a between-groups design: one group studied words auditorily (study-test modality mismatch; fluency attribution not expected) and one group studied words visually (study-test modality match; fluency attribution expected); both groups received visual memory tests. We found group differences in non-mnemonic fluency attributions to memory, with only the study-test modality match group showing repetition priming effects on "old" responses for both studied and unstudied words, as well on familiarity false alarms. Both groups showed old/new ERP effects in the 300-500ms time window at frontal sites and in the 500-800ms time window at parietal sites. In addition, there were ERP priming effects in the 300-500ms time window with more positive amplitudes of ERPs associated with primed versus unprimed words; importantly, there were no group differences in ERP priming effects, suggesting that they reflect perceived processing fluency of the primed versus unprimed words and not the attribution process. Finally, we performed a dynamic causal modelling (DCM) analysis and found that the forward connection from the right PRC to the right DLPFC showed weaker connectivity strength when the non-mnemonic fluency attribution to memory was switched on (i.e., for the study-test modality match group compared to the study-test modality mismatch group). These findings highlight the role of the right PRC and right DLPFC coupling in the fluency attribution process.

3.2. Introduction

Recognition memory judgments can stem from a *feeling* of having been exposed to a stimulus in the past (i.e., familiarity-based memory) or from a conscious retrieval of details about the previous exposure(s) to a current stimulus (i.e., recollection-based memory) (Yonelinas, 2002). There is growing body of research empirically supporting the idea that familiarity-based recognition memory can rely on non-mnemonic signals in certain circumstances. Fluency of a stimulus or the speed of its processing can be used as a cue for prior exposure. Experimentally increasing the fluency of stimuli during the testing phase of a recognition memory task has been shown to increase the proportion of "old" responses participants make for both studied and unstudied stimuli (e.g., Jacoby & Whitehouse, 1989; Westerman et al., 2002). Although increasing fluency of test stimuli is reflected in faster response times of both familiarity- and recollection-based memory judgments (e.g., Park & Donaldson, 2016; Chapter 2 of this thesis), it has been consistently reported that fluency affects the proportion of familiarity-based recognition decisions (Rajaram, 1993; Taylor & Henson, 2012; Woollams et al. 2008; Chapter 2 of this thesis). This effect has been explained through a fluency-attribution-to-memory hypothesis, where stimuli that are processed faster are judged as more familiar. The present chapter focuses on the investigation of this non-mnemonic fluency attribution to memory, how can it be switched on/off, and the mechanisms underlying it.

While Jacoby and Whitehouse (1989) found that experimentally induced fluency is (mis)attributed to memory when participants are not aware of its actual source, Whittlesea and Williams (2001a and 2001b) proposed that it is the surprising feature of fluency which makes it likely to be judged as evidence for prior exposure in the context of a recognition memory test. Along the same line, Westerman (2008) found that when fluent stimuli are rare (e.g., only 10% or 33% of trials in a test list are fluent compared to the rest), participants are more likely to endorse them as "old" even when they are not. Study-test modality match also modulates fluency attribution to memory (Miller et al., 2008; Westerman et al., 2002). When study and test modality do not match, participants do not attribute fluency to memory. This might be due to the fact that, although they experience fluency during the memory test, this cue is not relevant for their memory decisions.

Using EEG, it has been consistently reported that when fluency is induced by priming (i.e., preceding a target word by a prime or a sentence stem that increases the speed of processing), fluent stimuli are associated with more positive- or less negative- going ERPs compared to unprimed stimuli. These effects are found on an early P2-like component peaking at ~200ms following target onset (Li et al., 2017; Wang et al., 2020; Woollams et al., 2008), but also in a similar time window with the FN400 component (i.e., the frontal old/new effect), peaking ~400ms (Kurilla & Gonsalves, 2012; Li et al., 2017; Lucas et al., 2012; Park & Donaldson, 2016; Wolk et al., 2004). Fluency has also been manipulated through contrast changes, with clear stimuli being perceived more fluently than blurry stimuli. By using this method, blurry (i.e., non-fluent) stimuli were associated with more positive going ERPs than clear (i.e., fluent) stimuli between 280-400ms when clear and blurry stimuli were blocked, but not when they were presented interleaved within the same test list (Leynes & Zish, 2012) and between 180-260ms and 400-500ms following target onset (Stróżak, Leynes & Wojtasiński, 2021). The difference in how fluency was induced in these two studies might be connected to the reverse priming effect in ERPs; authors suggesting that the parietal distribution of the effect might indicate additional attentional resources allocated to blurry compared to clear words. In terms of topography of ERP priming effect, the early priming effect has a fronto-central topography (Li et al., 2017), whereas the later FN400-like ERP priming effect has a more posterior topography that, importantly, is different from the FN400 more frontal topography (Lucas et al., 2012; Woollams et al., 2008).

The recently proposed integrative memory model (Bastin et al., 2019) highlights the role of an attributional system that on the basis of mnemonic and non-mnemonic signals can lead to a subjective feeling of familiarity. The model conceptualises familiarity-based memory as relying on fluency signals which can sometimes stem from sources unrelated to memory. Bringing together all these findings and the theoretical framework of the integrative memory model, it could be suggested that the neural mechanism of fluency attribution to memory relies on the interaction between brain regions involved in monitoring the fluency of a stimulus (i.e., the perirhinal cortex (Dew & Cabeza, 2013)) and a prefrontal area involved in monitoring familiarity-based memory retrieval (i.e., right dorsolateral prefrontal cortex (Fletcher & Henson, 2001)).

The modality (mis)match paradigm of Westerman et al. (2002) provides an ideal way to study fluency attribution to memory in terms of how the neural system might switch on/off when participants use fluency as a cue for prior exposure or not. The main reason for this is because relevance of fluency for prior exposure is manipulated by changing the study context between groups, but crucially, keeping the memory test phase identical. A different modality of the study phase could render visual fluency during the test phase irrelevant for prior exposure, as shown by Westerman et al. (2002), Miller et al. (2008) and our results reported in Chapter 2 of this thesis. Therefore, the present experiment investigated fluency (mis)attribution to memory using a between-group design. Participants in one group studied the words visually (study-test modality match group) and participants in the other group studied the words auditorily (study-test modality mismatch group), while their brain activity was recorded using EEG. In both groups, we used masked repetition priming during the test phase to increase fluency of half of the words.

We were interested to investigate changes in terms of amplitude of priming- and memory- sensitive ERP components (i.e., P2, FN400, and LPC) between groups, as well as connectivity between sources using dynamic causal modelling (DCM) for evoked responses. DCM is an approach to investigate the dynamics of the causal interactions between brain regions (i.e., the causal influence of activity in one region on the activity change in another region); it was first developed for fMRI time series (Friston, Harrison & Penny, 2003) and later adapted for evoked responses (David et al., 2006). In the DCM framework, the brain is conceptualised as a system that receives inputs and generates outputs. Inverting DCM on ERP data consists of estimating sources of activity and their dynamics at the same time (David et al., 2006). DCM for evoked responses inverts an extended forward model using priors about the location of sources and generates parameters about the causal interactions between specified sources. Following model estimation, Bayesian model selection is then used to identify models that have the highest probability to explain the data, based on their Bayes factor or log-evidence (Stephan et al., 2009).

Predictions of results. Based on previous findings, we expected behavioural priming effects in the study-test modality match group (i.e., visual study group), but not in the study-test modality mismatch group (i.e., auditory study group), with an increased proportion of "old" and "familiar" responses for primed versus unprimed words. ERP-wise, priming effects were expected in the P2 (150-250ms) and in the FN400 (300-500ms) time windows, with more positive amplitudes of ERPs associated with primed versus unprimed words. If any component reflects fluency and not attribution, then there should be an effect of priming and no difference in priming effects between groups. If, however, a component reflects the attribution process, such an interaction should occur. A more direct way to assess this latter hypothesis would be to explicitly model the sources and their interactions (effective connectivity via DCM) and to look for group differences in connections in the model. Therefore, we expected group differences to occur at the level of fluency attribution to memory; at the neural level, these could take the form of group differences in the connectivity between PRC (associated with fluency) and the right DLPFC (associated with retrieval monitoring).

3.3. Methods

Design. The experiment was conducted as a 2 (study modality: Auditory (A) and Visual (V)) x 2 (prime type: matching or mismatching word) x 2 (study status: studied or unstudied) mixed factorial design, with prime type and study status as within-participants factors and study modality as between-participants factor. The key ERP comparison of interest to isolate the attribution process is between groups (and/or interaction between group and priming).

Participants. Fifty-six participants were randomly allocated to the Auditory study or the Visual study groups. For a power of 0.85 to detect a medium-sized effect of priming on behavioural responses in a repeated measures design with two levels (i.e., a Cohen’s d equal to 0.55), a sample of 24 participants per group was needed. We over-recruited in anticipation of participant removal due to noise or odd behavioural performance. Due to technical issues, incomplete datasets were recorded for three participants, two in the visual and one in the auditory study group. Thus, 25 datasets in the Visual group and 28 datasets in the Auditory group were analysed. Participants were excluded from further analyses if they made many recollection false alarms (>3%; 3 participants). When they understand the instructions of the R/K paradigm, participants are not likely to make recollection false alarms; across the experiment, the median of recollection false alarms was 1, with 22 participants not making any).
The interquartile range (IQR = quartile 3 – quartile 1) was calculated and the value of Q3 (quartile 3) + 1.5*IQR for recollection false alarms was used as guidance for participant exclusion; however, we decided to keep more participants than suggested by this rule given that overall, the proportion of recollection false alarms was very low (see Supplementary materials for a histogram). Analyses are reported on 24 participants in the visual group (mean age = 22.75, SD = 5.42 years, 17 female), and 26 participants in the auditory group (mean age = 21.12, SD = 2.85 years, 18 female). All participants were

recruited through online advertisements and offline posters displayed in the campus of the University of Manchester. Participants reported to be in good neurological health with normal or corrected-to-normal vision and hearing. They were tested individually in an electrically shielded EEG recording booth and received either Psychology course credits or financial compensation for their participation.

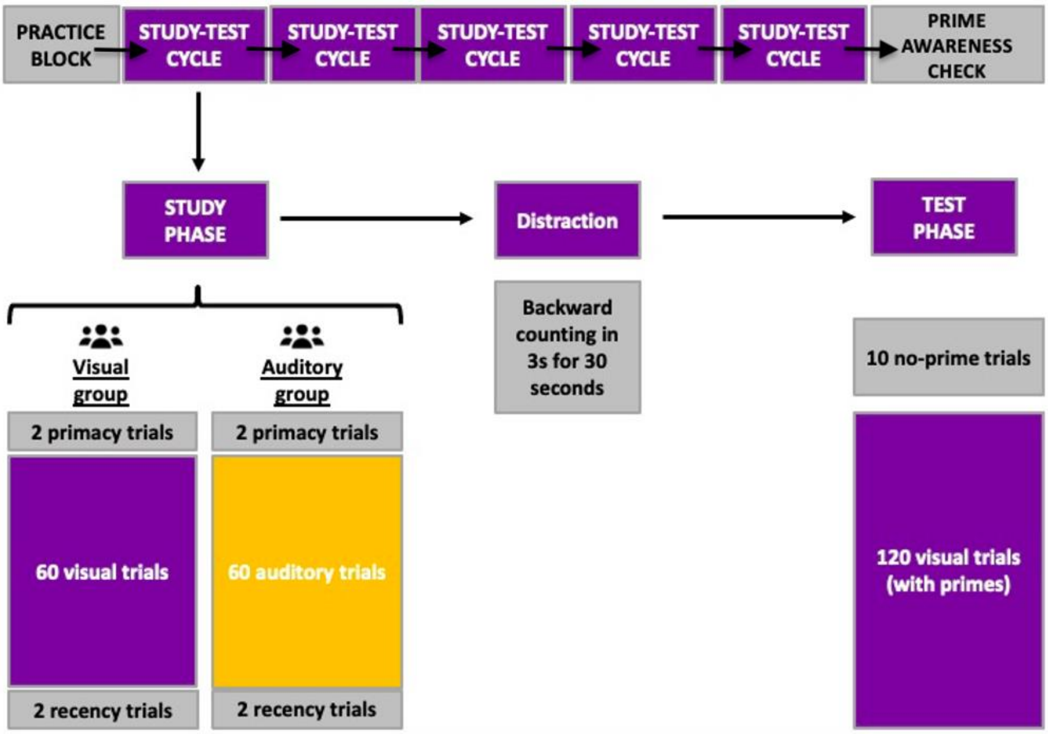


Figure 3.1. Schematic illustration of the structure of the experiment. Top row: session procedure (left-to-right); bottom: one study-test cycle expanded to show study phase (different for the 2 groups), distraction task, and test phase (same both groups). Colours shown here are only for illustrative purposes; the screen was grey for all trials.

Stimuli. The stimuli of interest consisted of 600 words mostly taken from the stimulus set used in Taylor & Henson (2012). All stimuli were between 3 and 9 letters long (M = 5.92, SD = 1.51) and had written frequencies between 1 and 150 per million (M = 29.27, SD = 32.15, based on CELEX, Medler & Binder, 2005). Targets cycled through conditions (auditory study/visual study/unstudied) across participants. In addition to the stimuli of interest, we used 62 fillers having similar word length and written frequencies as the stimuli of interest. The stimuli were divided into 40 lists of 15 word pairs. Within each list, the matching primes were the same as the target words and the mismatching primes were shuffled matching primes, pseudo-randomly re-paired with target words, with an initial randomisation and a manual check to ensure primes and target were unrelated (and re-arranged as necessary).

Auditory stimuli. To the auditory stimuli used in Chapter 2, 120 more words were added from the pool of targets and primes used in Taylor and Henson's study (2012); these were generated using Apple voice synthesizer (British accent, Daniel, at a frequency of 200 wpm) and were validated by British English native speakers using a similar procedure as in the previous experiment reported in Chapter 2 of this thesis.

Procedure. The experiment consisted of a short practice block, 5 study-test cycles of interest, and a short prime awareness check. We used 5 study-test cycles of interest instead of 4 (as used in the experiment reported in Chapter 2 of the thesis) in order to increase the number of trials, for being able to extract ERPs for all conditions of interest. Stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). During encoding, the Visual group studied all words visually and the Auditory group studied all words auditorily in headphones. Each test list consisted of 10 initial trials that were not preceded by primes + 120 target words (60 studied and 60 unstudied). Regardless of the study modality, both groups received a visual memory test (see Figure 3.1). The encoding task was to indicate whether the words presented on the screen are interesting or not by button press (see top Figure 3.2). The distractor task lasted 30 seconds and participants were required to count backwards in threes from a given number on the screen.
In order to test participants' memory for the studied words, a modified version of the R/K paradigm (Tulving, 1985) was used, in which we replaced 'know' with 'familiar' (as in Taylor & Henson, 2012; see Figure 3.2). During the test phase, the target word appeared on the screen for 1s during which participants were asked not to press any button, in an attempt not to contaminate the evoked responses associated with memory with the motor responses. Then, the word disappeared, and participants first indicated whether it was presented in the study phase ('old') or not ('new'); for words judged as old, they were prompted to indicate whether they recollected the event of encountering the word in the study phase ('remember' response) or whether the word was just 'familiar'. Participants responded using their index and middle fingers of the dominant hand. Throughout the paper, 'familiar' responses will be referred to as K and 'remember' responses as R. For both the old/new judgment and the R/K judgment, participants were told to respond as accurately as possible within the

2s time limit (responses made after the time limit were not recorded and the trials considered invalid).

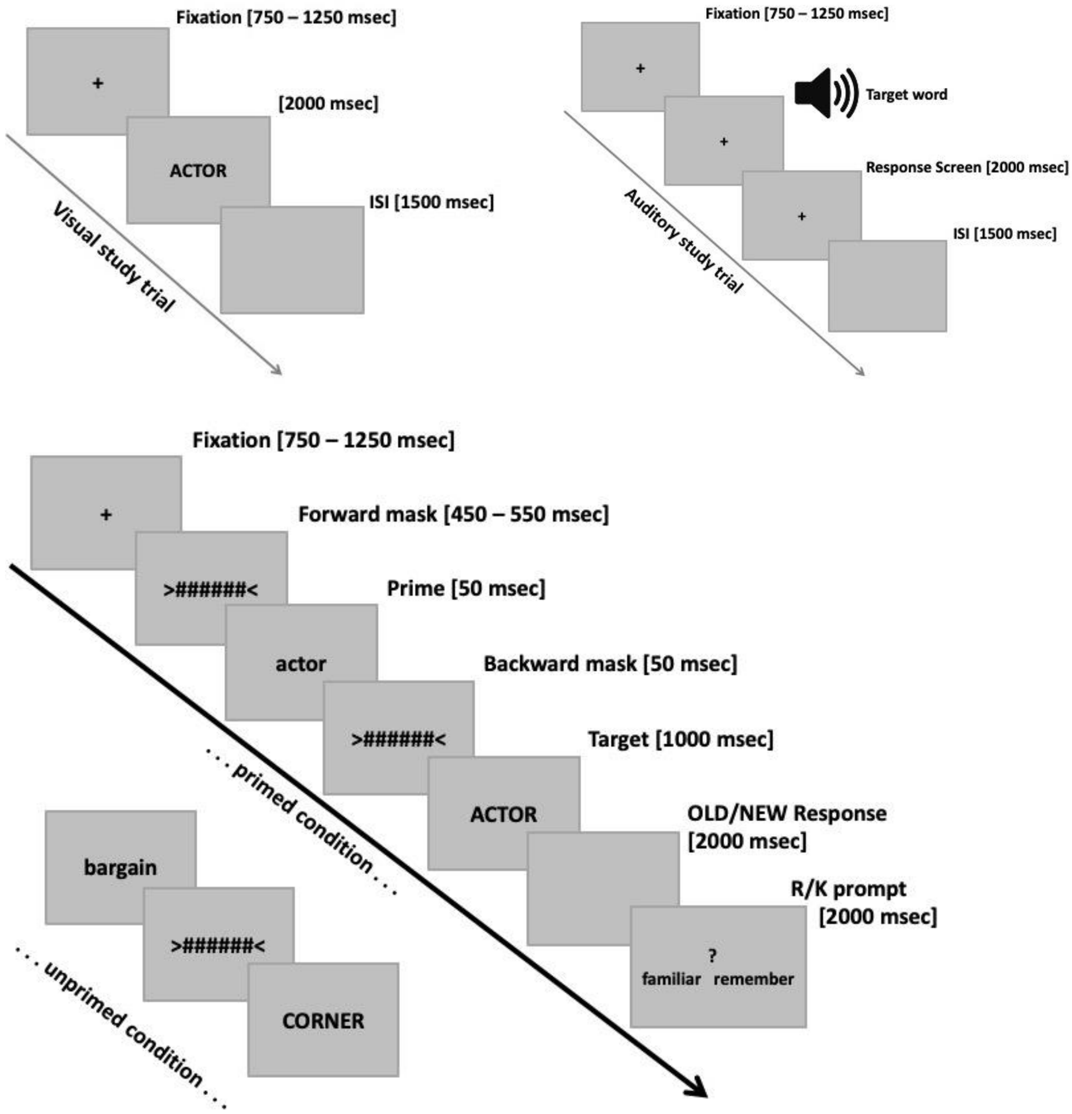


Figure 3.2. Schematic representation of trials during the study phase (top) and during the test phase (bottom) of the experiment.

Both groups completed a short practice block to familiarise themselves with the tasks. The experimenter briefly explained the experiment, then participants completed a short practice block consisting of a short study list, the distracting task and a short test list. After this, the experimenter checked whether participants understood the difference between 'familiar' and 'remember' options (i.e., familiarity/recollection). Once this distinction was clear for participants, they started the actual experiment and completed 5 blocks, having the option to take breaks in-between them if needed (see Figure 3.1).

Subjective Prime Awareness Check. Following the completion of the experiment, participants were asked *whether they noticed anything unexpected during the experiment*. If they did not mention the presence of the primes, the experimenter asked whether they noticed the hidden words preceding the targets in the test phases. Participants' responses were coded as follows: 1 – unaware, 2 – aware of something being flashed but not able to read the prime words, 3 – aware of the prime words, 4 – aware of the prime words and aware that sometimes they were the same as the target words they preceded.

EEG data acquisition. Continuous EEG data were recorded with a BIOSEMI Active-Two system (BioSemi, Amsterdam, The Netherlands) at a 512Hz sampling rate. EEG was recorded from 64 silver-silver chloride (Ag-AgCl) pin-in type electrodes placed according to the extended 10/20 system on an EEG cap. Vertical and horizontal eye movements (EOG) were recorded via flat-type electrodes placed approximately 2cm above and below the right eye and 2cm lateral to each eye. An electrode was placed on each mastoid and this signal served as offline re-referencing. CMS (Common Mode Sense) and DRL (Driven Right Leg) electrodes were used as online reference.

EEG data pre-processing was performed in MATLAB (The MathWorks, Inc., Natick, Massachusetts, United States) with SPM 12 toolbox (https://www.fil.ion.ucl.ac.uk/spm/). The data were first re-referenced offline to mastoids, then down-sampled to 200 Hz, high-pass filtered at 0.1 Hz, low-pass filtered at 100 Hz and segmented into 2100ms epochs from 500ms before to 1600ms after prime onset. Baseline correction was performed using the 100ms before prime onset. Independent component analysis (ICA) was used to project eye-blink artefacts out of the data (using EEGLAB; Delorme & Makeig, 2004) and custom functions (Taylor, 2018, https://github.com/jason-taylor/spm_eeglag). ICA was performed on epoched EEG data using EEGLAB's 'runica' algorithm ('extended' option, 32 components). Each independent component's time-course was correlated with VEOG's time-course (after band-pass filtering between 1-20Hz), and channel weight 'topography' was correlated with the topography of the average eye-blink (blink events detected automatically using SPM's artefact module). The component that had the highest coefficient of temporal*spatial correlation was removed. The artefact-cleaned data were then low-pass filtered at 30 Hz, and further cropped into epochs -100ms and 1100ms around prime onset. Baseline correction was performed again using the 100ms time window before prime onset. Trials with EEG channel amplitudes exceeding +/-100μV were rejected, and channels exceeding this threshold on >20% of epochs were marked as bad and excluded from analysis. On average, 114 out of ~600 trials were rejected (11-276, SD = 66.78). Finally, data were averaged over epochs, resulting in one ERP per condition per participant.

Behavioural analysis on proportions of responses. In order to replicate previous behavioural findings (Chapter 2 of this thesis; Westerman et al., 2002), a 2 (group: visual, auditory) x 2 (priming: matching, non-matching) x 2 (study status: studied, unstudied) ANOVA was performed on the proportions of "old" responses. The same analysis was done on the proportions of K responses. A 2 (group) x 2 (priming) ANOVA was performed on the proportion of R responses. It was predicted that there will be significantly more "old" responses for primed than for unprimed words in the visual study group, but not in the auditory group; so, an interaction between group and priming was expected. This effect was predicted to be driven by K responses, thus similar patterns of results were expected for the proportions of K responses, but not for R responses.

Behavioural analyses on response times were not performed given that participants only responded to the words after they disappeared from the screen (1s following onset). RTs would have been an indirect way of showing the increased processing fluency of primed versus unprimed words (as mentioned in Chapter 2). However, given that we recorded EEG data in this experiment, ERP priming effects will be a more direct way of measuring fluency than response times.

EEG analysis consisted of two main steps: (1) a canonical ERP analysis on averaged amplitudes of components sensitive to priming and memory effects, and (2) a DCM analysis to investigate group differences in the connectivity strength between brain regions of interest. These will be explained in detail below.

Canonical ERP analysis: Components of interest. Based on previous studies (e.g., Wang et al., 2020; Woollams et al., 2008), ERP amplitudes on components P2, FN400 and LPC were analysed. The time windows for each component were established by averaging across all conditions and all participants and visually inspecting the peaks – a method that is unbiased by group or condition differences of interest. The P2 was defined as 50-250ms following target onset and was expected to be sensitive to priming manipulations; a cluster of central electrodes (C1, Cz, C2) was chosen and ERPs associated with primed trials were predicted to be more positive going than ERPs associated with unprimed trials. Compared to previous research (e.g., Woollams et al., 2008), the P2 component in this study had an earlier onset, thus we defined a time window to fully capture the peak. The FN400 was defined as 300-500ms following target onset and for this time window; a frontal cluster of electrodes (F1, Fz, F2) was selected and ERPs were expected to be more positive going for old trials compared to new trials (i.e., K hits and R hits > CRs). The LPC was defined as 500-800ms following target onset and was expected to be sensitive to recollection-based responses; a parietal cluster of electrodes was selected (P1, Pz, P2) and ERPs associated with R hits were expected to be more positive going than ERPs associated with K hits and CRs. For each component, time-window and electrode-cluster-averaged amplitude was computed for the following: K hits, R hits and CRs. ERPs associated with Misses were not included in the analysis due to the low number of trials (<12) in 8 participants across the sample. One participant in the Visual group had noisy data (i.e., 6 channels were marked as bad which included Pz) and was excluded from this analysis; and three other participants (1 from the Visual group and 2 from the Auditory group) were excluded due to low number of trials (<12) in the conditions of interest (i.e., K hits primed/unprimed, R hits primed) after artefact rejection. Therefore, the reported ERP analysis was performed on 22 participants in the Visual group and 24 participants in the Auditory group.

Three 2 (group) x 3 (responses: K Hits, R Hits, CRs) x 2 (priming: primed, unprimed) ANOVAs were performed on time-window- and electrode-cluster-averaged amplitude: P2 in the central cluster, FN400 in the frontal cluster, and LPC in the parietal cluster. We expected memory effects in both groups, with more positive going ERPs associated with K Hits and R Hits compared to CRs (FN400 old/new effect (e.g., Lucas et al., 2012; Woollams et al., 2008) and more positive going ERPs associated with R Hits compared to K Hits in the LPC time window. Furthermore, we predicted more positive going ERPs associated with primed versus unprimed trials in the P2 time window (Woollams et al., 2008).

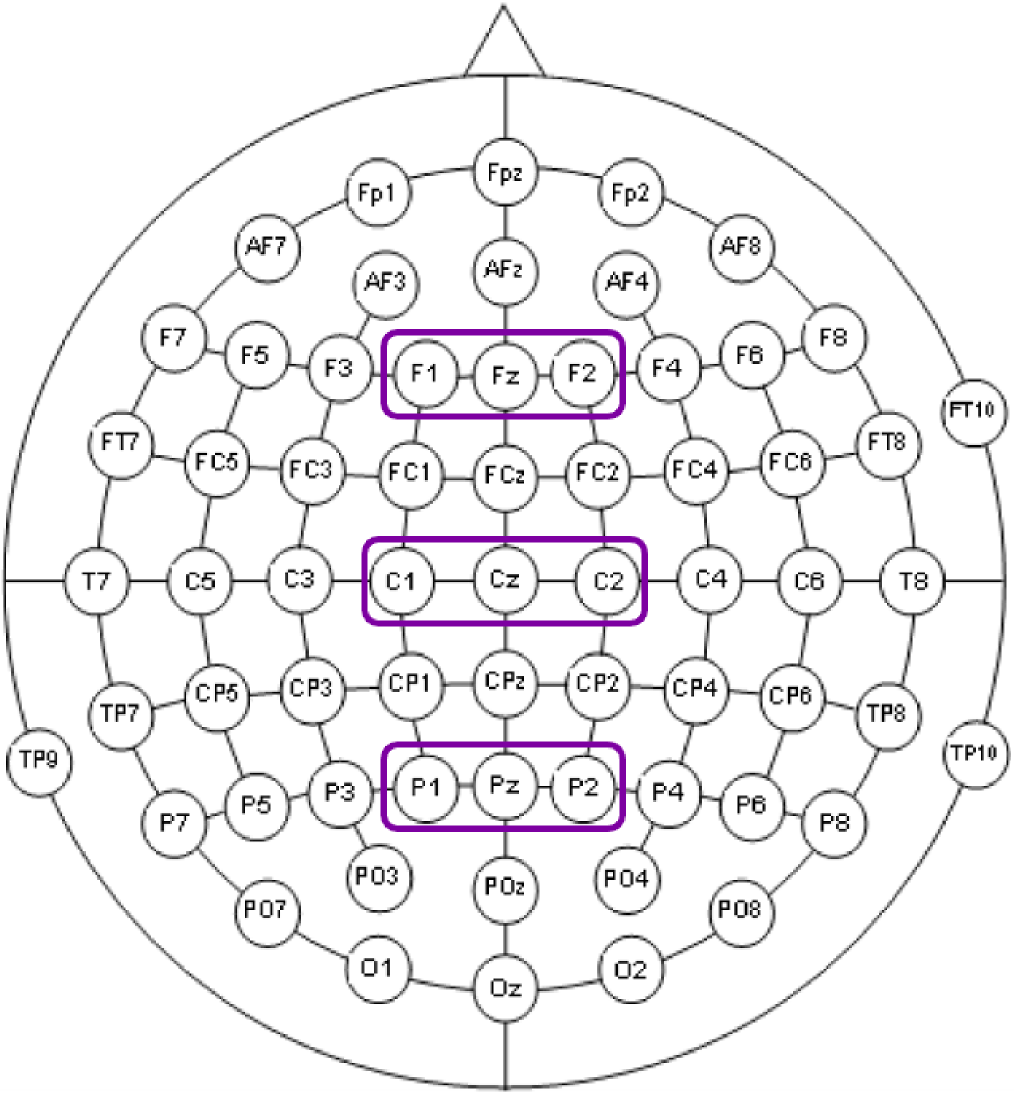


Figure 3.3. Clusters of electrodes ERP amplitudes were averaged across. F1, Fz, F2 = frontal cluster for the 300-500ms time window; C1, Cz, C2 = central cluster for the 50-250ms time window; P1, Pz, P2 = parietal cluster for the 500-800ms time window.

DCM: Selection of regions of interest. DCM models were estimated for the 0-500ms time window following target onset. Dew and Cabeza's (2013) study suggested a link between fluency and PRC connectivity to visual areas and right lateral prefrontal frontal areas. In addition, Fletcher and Henson's (2001) review identified the right dorsolateral prefrontal cortex to be associated with retrieval memory. Based on these findings, we included 5 regions of interest: left and right visual cortices (word form area: -45, -57, -12 (as reported in Chen et al., 2019) and the ipsilateral visual area: 45, -57, -12), left and right perirhinal cortices/medial temporal lobe areas (PRC/MTL: -37, -15, -27 and 37, -15, -27 (as reported in Dew & Cabeza, 2013)), and right dorsolateral prefrontal cortex (DLPFC: 48, 30, 21 (as reported in Henson, Shallice & Dolan, 1999)).

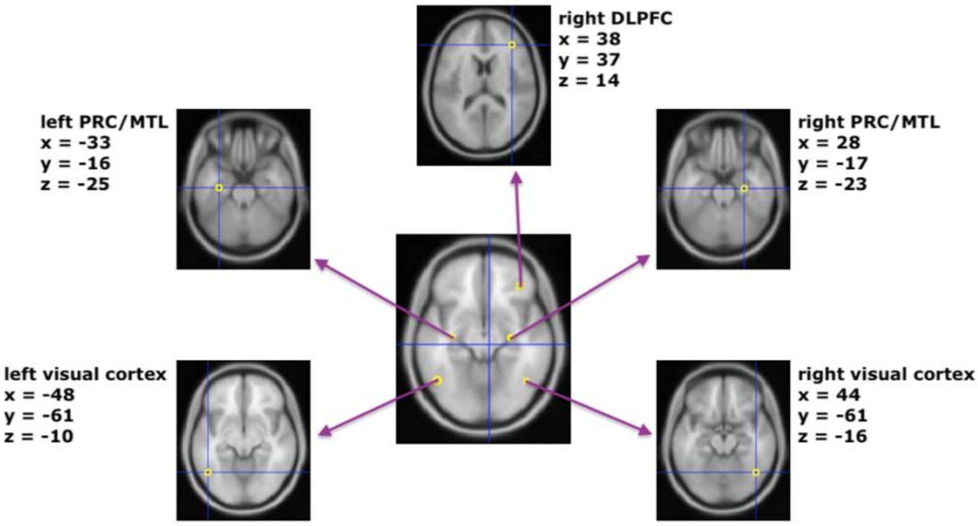


Figure 3.4. MNI coordinates of regions of interest included in the model that was estimated in all individual participants. Locations of dipoles are the new optimized ones. The image in the centre is just for reference, z coordinates differing for each ROI as shown in individual images.

DCM: Model selection approach. The grand average across all participants was first computed. We specified 24 models (see Figure 3.5) and estimated them first on the grand averaged dataset, keeping the primed/unprimed K hits, R hits and CRs conditions. We inverted the models on the 0-500ms time window following target onset, because we wanted to look at fluency attributions to familiarity and the FN400 component is captured between 300-500ms. Although DCM for evoked responses is mainly designed for early components, there is a study where 0-500ms time window was used, for a similar reason (i.e., the interest was in the N400 component) (Penny et al., 2018). Within the DCM framework, we predict group differences at the level of connectivity strengths in extrinsic connections (Matrix A), so we did not specify modulatory effects of task (Matrix B). When estimating the models on the grand average, we allowed DCM to optimise the position of the dipoles; the optimised positions for the winning model are shown in Figure 3.4. The winning model was then estimated separately in each individual participant.

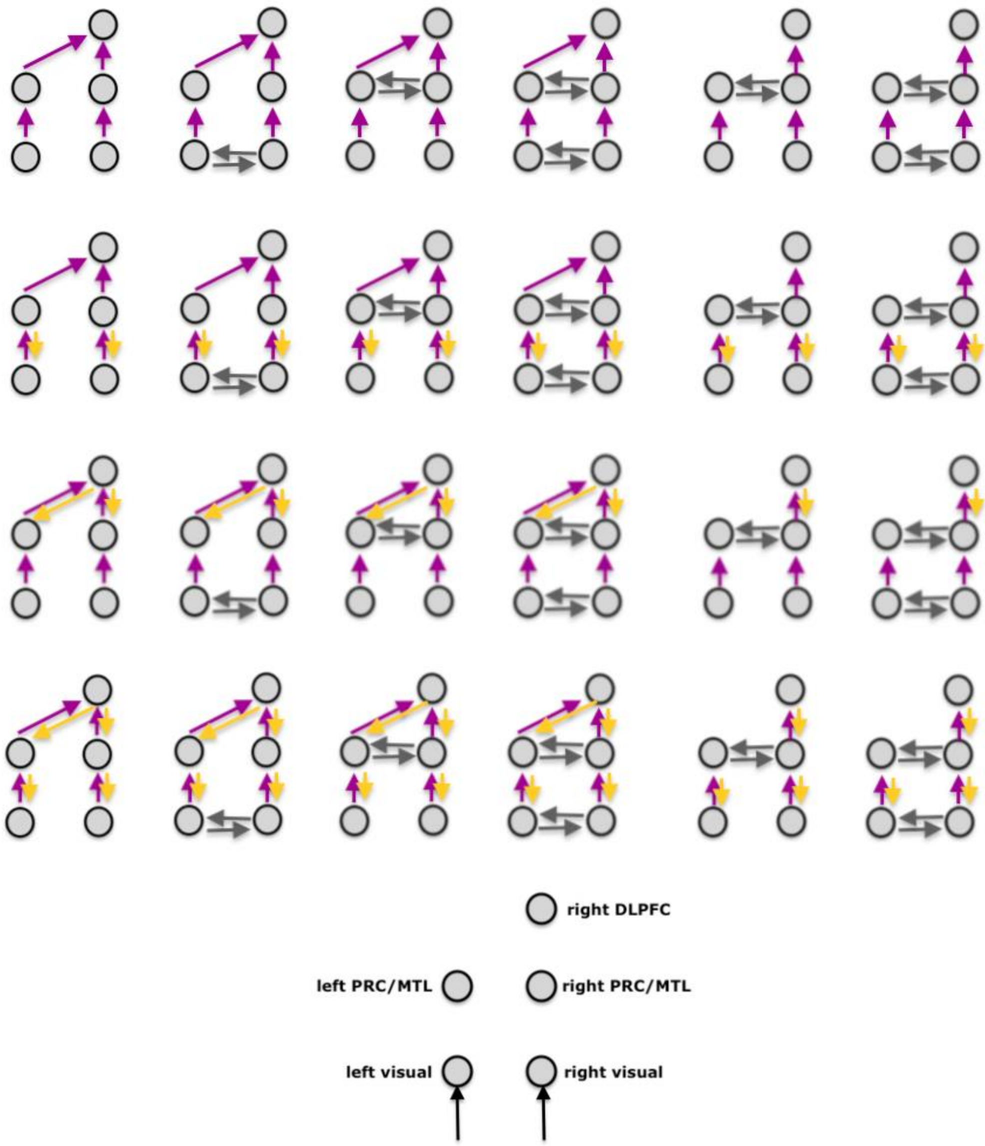


Figure 3.5. DCM models specified on the grand average data. The first row included only forward connections, the second row included backward connections from PRC/MTL areas to visual area, the third row included backward connections from DLPFC to PRC/MTL areas, and the forth row included backward connections between all areas we specified forward connections. The first column did not include any lateral connections, the second column included lateral connections between ipsilateral visual areas, the third column included lateral connections between PRC/MTL ipsilateral areas and the forth column included lateral connections between visual areas and between PRC/MTL areas. Models on the fifth column are the same as the ones on the third column, but with missing connections between left PRC/MTL and right DLPFC; models on the sixth column are the same as the ones on the forth column, but with missing connections between left PRC/MTL and right DLPFC. The aim was to compare families of

models (each row would be a family, and each column would be a family). The input regions were both visual areas. Purple arrows are forward connections, yellow arrows are backward connections, grey arrows are lateral connections (they do not map to visual/auditory study conditions in any way). Bottom: 'legend' model.

DCM: Group differences in source coupling parameters. Once a winning model was selected, it was estimated separately on each individual in each group. At this step, when estimating the model for each data set, we used the final locations of dipoles from the posteriors of the winning model (as they are shown in Figure 3.4), and we did not allow DCM to optimise the location of the dipoles for each individual. The maximum number of iterations was set to 128 for the individual model estimation. Six t-tests were performed to compare the connectivity strengths of six connections (from the winning model) between groups.

3.4. Results

3.4.1. Behavioural results*. Memory performance.* As an initial check, we compared memory performance (Hits – False Alarms) between the two groups. We also checked whether memory performance was above chance for K and R responses, separately (see Table 3.1). An independent t-test showed significant differences between groups in terms of memory performance ($t(1,48) = 2.512$, $p = .015$), with better memory performance in the Visual study group compared to the Auditory study group. Memory performance was above chance for both K responses ($t(1,49) = 13.645$, $p < .001$) and R responses ($t(1,49) = 16.547$, $p < .001$).

Table 3.1.

Memory performance for each group

Auditory study group			Visual study group		
Hits – FAs			Hits – FAs		
Overall	K	R	Overall	K	R
0.69 (0.16)	0.31 (0.15)	0.38 (0.18)	0.79 (0.11)	0.30 (0.17)	0.49 (0.18)

Note. Memory performance was calculated as Hits – False Alarms: overall, and for K and R responses separately. Standard deviations shown in parentheses.

Proportions of "old" responses. Mean proportions of responses for each condition are presented in Table 3.2 and Figure 3.6. The 2 x 2 x 2 (group by priming by study status) ANOVA on "old" responses showed a significant main effect of priming ($F(1,48) = 12.14$, $p = .001$, partial $\eta^2 = .202$) with primed words receiving more "old" responses than unprimed words, as expected; a significant main effect of group ($F(1,48) = 6.61$, $p = .013$, partial $\eta^2 = .121$) showing a higher proportion of "old" responses given by participants in the visual study group compared to the ones in the auditory study group (but not of interest); a significant main effect of study status ($F(1,48) = 1406.47$, $p < .001$, partial $\eta^2 = .967$) simply showing more "old" responses for studied versus unstudied words; a significant interaction group x study status ($F(1,48) = 6.31$, $p = .015$, partial $\eta^2 = .116$) (not of interest); and a significant interaction group x priming ($F(1,48) = 6.51$, $p = .014$, partial $\eta^2 = .119$) which was of main interest. Based on our hypothesis, we performed 4 t-tests to investigate the priming effects on "old" responses separately on studied and unstudied words, in each group. In the visual group, there was a significant priming effect on the proportion of "old" responses to studied words ($t(1,23) = 1.957$, $p = .031$, one-tailed) and a significant priming effect on the proportion of "old" responses to unstudied words ($t(1,23) = 3.650$, $p < .001$, one-tailed). In the auditory group, there were no significant priming effects on "old" responses to either studied ($t(1,25) = .546$, $p = .295$, one-tailed) or unstudied ($t(1,25) = .298$, $p = .384$) words.

Table 3.2.

Mean proportions of responses to studied or unstudied words in each group

Response	Auditory study group				Visual study group			
	Studied		Unstudied		Studied		Unstudied	
	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed
K	0.38 (0.15)	0.36 (0.14)	0.06 (0.06)	0.06 (0.06)	0.37 (0.15)	0.37 (0.17)	0.08 (0.08)	0.06 (0.05)
R	0.39 (0.18)	0.41 (0.17)	0.03 (0.05)	0.03 (0.04)	0.50 (0.18)	0.49 (0.19)	0.01 (0.01)	0.01 (0.01)
New	0.23 (0.14)	0.23 (0.14)	0.92 (0.07)	0.92 (0.06)	0.13 (0.09)	0.14 (0.09)	0.93 (0.07)	0.94 (0.05)

Note. Standard deviations in parentheses. K – "familiar", R – "remember".

Proportions of K responses. A 2 x 2 x 2 (group by priming by study status) ANOVA on proportions of K responses showed a significant main effect of priming ($F(1,48) = 9.52$, $p = .003$, partial $\eta^2 = .165$) in the expected direction (primed > unprimed), a significant main effect of study status ($F(1,48) = 182.02$, $p < .001$, partial η^2 = .791) simply showing participants made more K responses for studied compared to unstudied words. There was no significant main effect of group ($F(1,48) = .02$, $p = .904$, partial $\eta^2 < .001$) and no significant interactions (study status x group: $F(1,48) = .01$, $p = .920$, partial $\eta^2 < .001$; priming x group: $F(1,48) < .001$, $p = .992$, partial $\eta^2 < .001$; study status x priming: $F(1,48) = .07$, $p = .798$, partial $\eta^2 = .001$; study status x priming x group: $F(1,48) = 3.13$, $p = .083$, partial $\eta^2 = .061$).

Although the interaction group x priming was not significant, in light of the predicted patterns of results, planned contrasts were conducted to look at priming effects in each group. Planned paired-samples t-tests were performed separately for studied and unstudied words in each group, showing a priming effect only on K false alarms in the Visual study group ($t(1,23) = 3.337$, p = .003) and a nearly significant priming effect on K hits in the Auditory study group ($t(1,25) = 1.972$, p =.060), given a Bonferroni-corrected significance threshold of .025.

Proportions of R responses. The 3 x 2 (group by priming) ANOVA on R hits did not yield any significant effects. Response times are shown in Table 3.3. for reference, but we did not perform an analysis on them, given that participants made old/new judgments 1s after target onset.

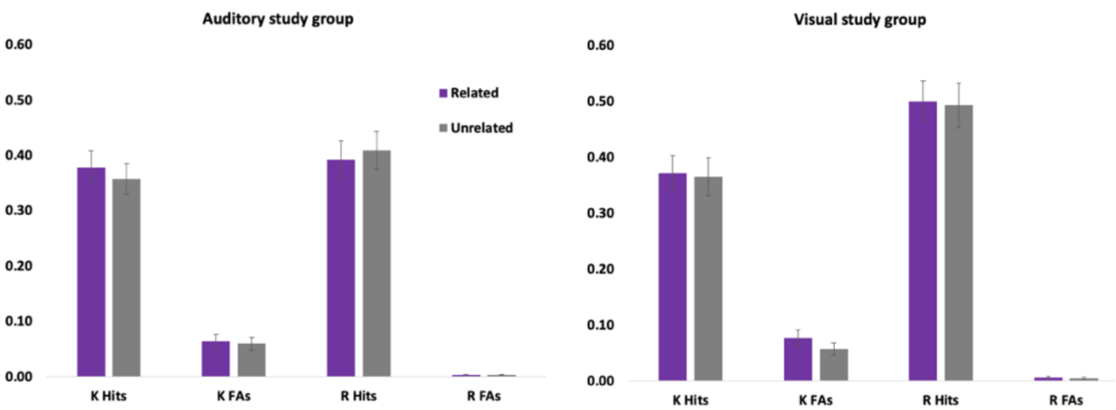


Figure 3.6. Proportions of responses for each condition across groups. Recollection false alarms were not analysed (although displayed in the graphs), given that participants made very few. Standard error bars.

In terms of prime awareness, 18 participants were unaware (5 in the auditory group and 13 in the visual group), 17 participants were only aware of something being briefly flashed (13 in the auditory group and 4 in the visual group), 13 participants could read some of the words (6 in the auditory group and 7 in the visual group) and 2 participants were aware that the primes were sometimes the same as the target they preceded (both of them in the auditory group). The pattern of results was similar when including the whole sample or a sub-sample of participants who were not aware of the primes (results of the main analyses are reported in Supplementary Materials).

Table 3.3.

Mean of median response times (ms).

Response	Auditory study group		Visual study group	
	Studied Primed	Studied Unprimed	Studied Primed	Studied Unprimed
K	419 (123)	447 (184)	347 (98)	390 (161)
R	336 (73)	336 (77)	315 (61)	322 (67)

Note. Standard deviations in parentheses. K – "familiar", R – "remember". The table shows values for the median RTs for "old" responses, subsequently judged as familiar (K) or remembered I, not the RTs for the familiar/remember judgment itself.

Summary of the behavioural results. The analysis on the proportion of "old" responses showed a priming effect (i.e., a higher proportion of "old" response for primed compared to unprimed words) in the Visual group only on both studied and unstudied words (with a stronger effect on unstudied words).

When separating "old" responses into K and R, analyses showed a significant priming effect on K responses only. Both groups made significantly more K responses for primed versus unprimed words; however, the Visual group showed a significant priming effect on K false alarms and the Auditory group showed a nearly significant priming effect on K hits. Overall, it appears that the priming effect on K responses was stronger in the Visual group compared to the Auditory group, in line with the predicted pattern.

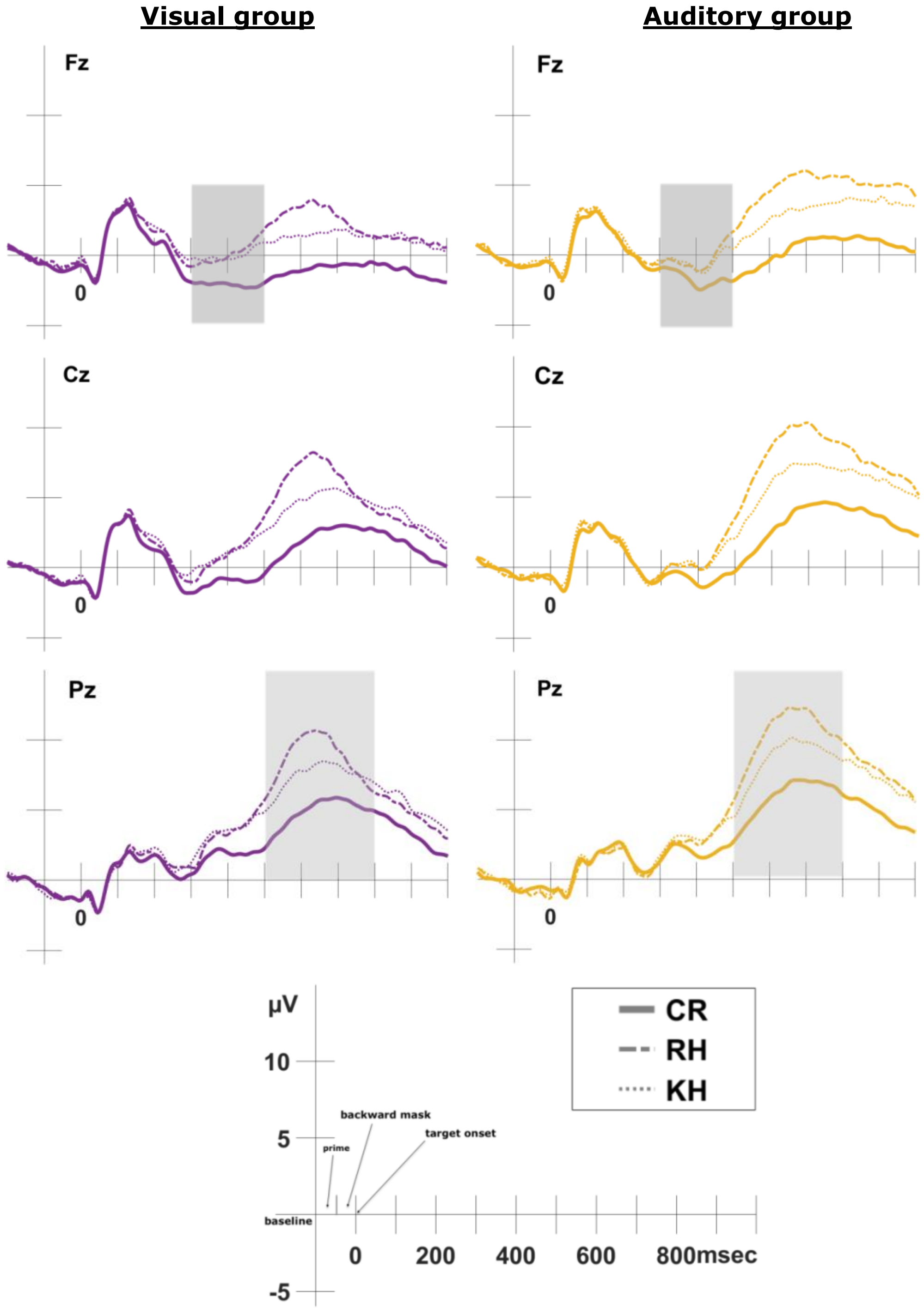


Figure 3.7. ERP memory effects in each group for 3 chosen electrodes, each representative for the analysed cluster. On the x-axis, -200 to -100 was the baseline used for correction; the '-100' time point was prime onset (the prime appeared on the screen for 50ms, being followed by the backward mask); '0' time point is the target onset. Grey areas show the time windows we averaged the ERP amplitudes across.

3.4.2. Canonical ERP results. The ERPs are displayed in Figures 3.7, 3.8 and 3.9. Figure 3.7 shows ERPs associated with K hits, R hits and CRs, collapsed across priming conditions, separately for the two groups. Figure 3.8 shows ERP priming effects in the Visual study group, and Figure 3.9 shows ERP priming effects in the Auditory study group.

P2 (50-250ms, central channels). The 2 (group) x 3 (response type) x 2 (priming) ANOVA did not yield a significant main effect of priming ($F(1,44) = .27$, $p = .606$, partial $\eta^2 = .006$) or a significant interaction between group and priming ($F(1,44) = 1.61$, $p = .211$, partial $\eta^2 = .035$), as we predicted. Visual inspection of ERPs suggests more positive going ERPs for primed versus unprimed trials across response types in the visual study group, whereas in the auditory study group, ERPs appear more negative going for primed versus unprimed K hits and R hits, and more positive going for primed versus unprimed CRs. A series of (one-tailed) planned contrasts were performed to compare the mean amplitudes of ERPs for primed versus unprimed trials, for each response type in each group. In the visual group, the primed versus unprimed contrast was significant for CR ($p = .049$), but not significant for K hits ($p = .310$) or R hits ($p = .135$). Similarly, in the auditory group, the primed versus unprimed contrast was marginally significant for CR ($p = .058$), but not significant for K hits ($p = .202$) or R hits ($p = .159$).

FN400 (300-500ms, frontal channels). The 2 x 3 x 2 ANOVA showed a significant main effect of response type ($F(2,88) = 22.31$, $p < .001$, partial $\eta^2 = .336$) across groups. Post-hoc tests were performed to compare the ERPs associated with each response type; paired samples tests showed significantly more positive going ERPs associated with K hits and R hits versus CR (K hits vs CR: $t(1,45) = 5.533$, $p < .001$; R hits vs CR: $t(1,45) = 6.765$, $p < .001$), but no difference between ERPs associated with K hits and R hits ($t(1,45) = .280$, $p = .781$). These results are following the expected pattern of memory effects on FN400. Also, there was a significant main effect of priming ($F(1,44) = 21.04$, $p < .001$, partial $\eta^2 = .324$), with more positive going ERPs associated with primed versus unprimed trials showing that this component is sensitive to priming. Finally, there was a significant interaction response type x priming ($F(2,88) = 3.95$, $p = .023$, partial $\eta^2 = .082$) across groups. Post-hoc tests were performed to compare ERPs associated with primed versus unprimed trials for each response type: there was a priming effect on ERPs associated with R hits and CR, but not with K hits, with more positive going ERPs for primed versus unprimed trials (R hits: $t(1,45) = 4.378$, $p < .001$; CR: $t(1,45) = 4.143$, $p < .001$; K hits: $t(1,45) = 1.510$, $p = .138$). A series of (one-tailed) planned contrasts were performed to compare the mean amplitudes of ERPs for primed versus unprimed trials, for each response type in each group. In the visual group, the primed versus unprimed contrast was significant for all response types: K hits ($p = .040$), R hits ($p = .001$), and CR ($p = .001$). In the auditory group, the primed versus unprimed contrast was significant for R hits ($p = .009$) and CR ($p = .016$), but not for K hits ($p = .284$). The rest of the main effects and interactions were not significant (Fs < 1, *p*s > .05)

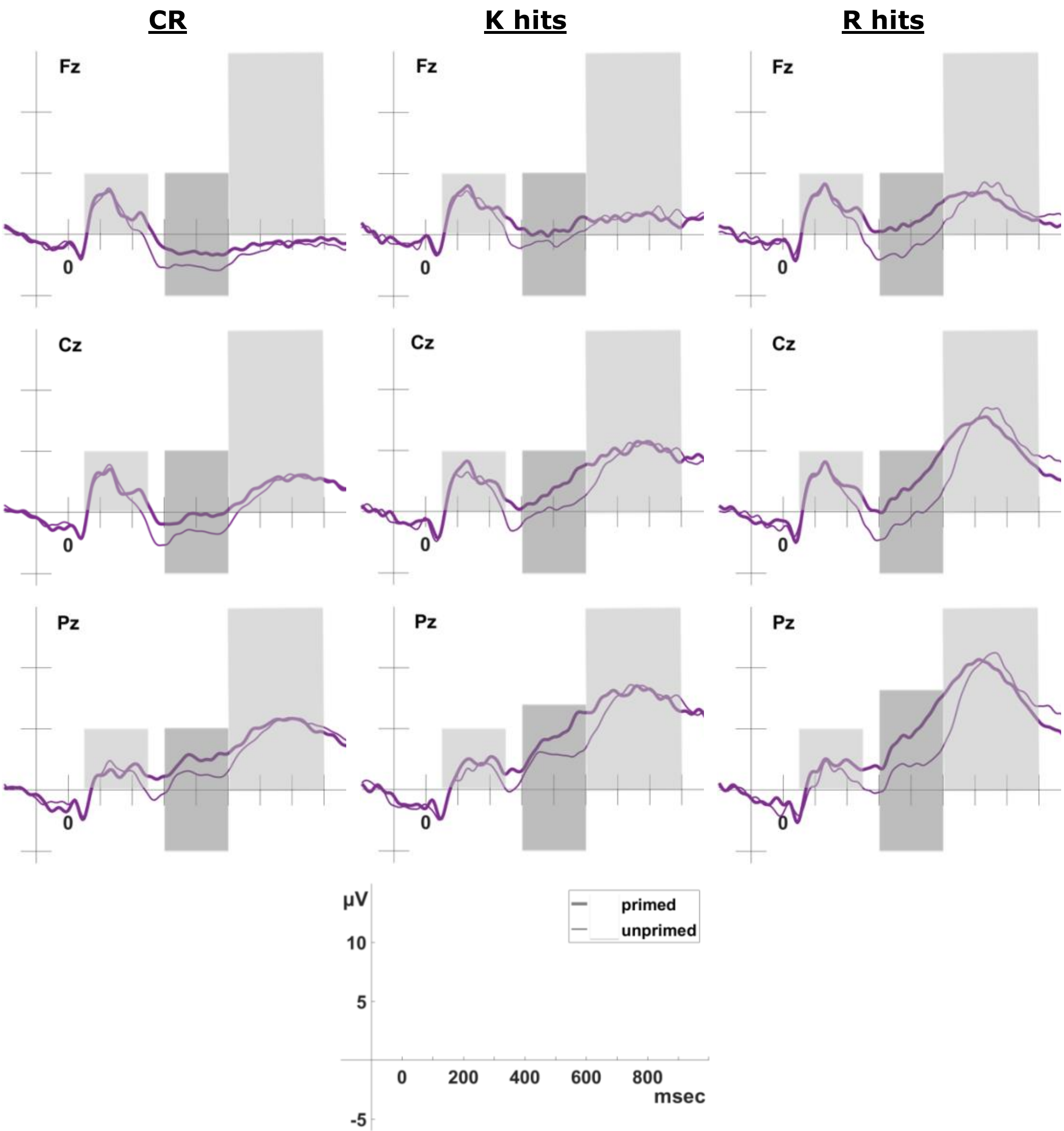


Figure 3.8. ERP priming effects in the visual group for each response type. On the x-axis, -200 to -100 was the baseline used for correction; the '-100' time point was prime onset (the prime appeared on the screen for 50ms, being

followed by the backward mask); ‘0’ time point is the target onset. Grey areas are the time windows we averaged ERP amplitudes across.

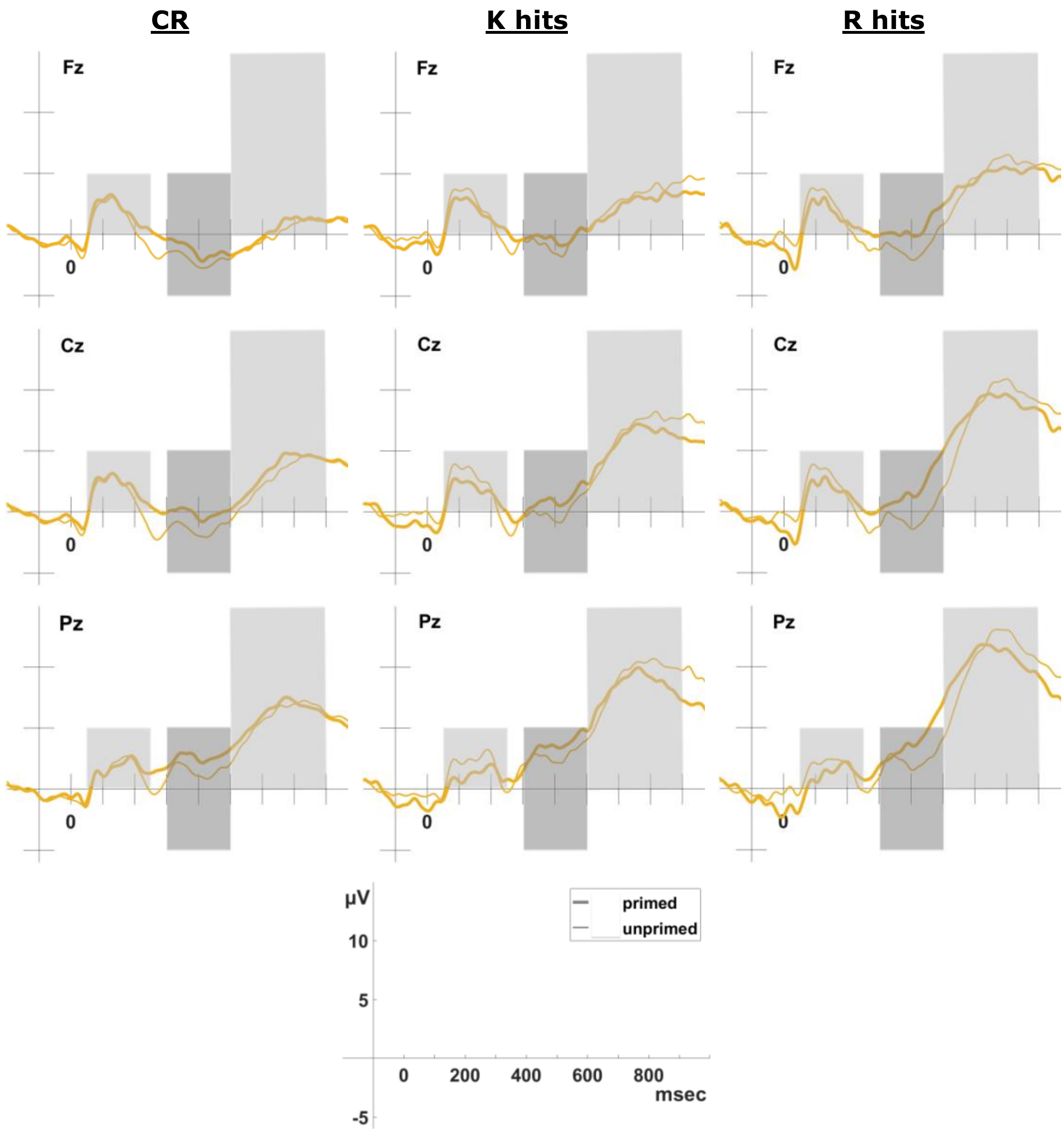


Figure 3.9. ERP priming effects in the auditory group for each response type. On the x-axis, -200 to -100 was the baseline used for correction; the ‘-100’ time point was prime onset (the prime appeared on the screen for 50ms, being followed by the backward mask); ‘0’ time point is the target onset. Grey areas are the time windows we averaged ERP amplitudes across.

LPC (500-800ms on parietal channels). The 2 x 3 x 2 ANOVA yielded a significant main effect of response type (F(2,88) = 45.32, p < .001, partial η^2 = .507) across groups, with paired samples post-hoc tests showing significantly more positive going ERPs associated with R hits compared to ERPs associated with K hits ($t(1,45) = 4.268$, $p < .001$), which were, in turn, more positive going than ERPs associated with CR ($t(1,45) = 5.912$, $p < .001$); R hits vs CR: $t(1,45) = 8.739$, $p < .001$. This is the expected pattern of memory effects for the LPC time window. A series of (one-tailed) planned contrasts were performed to compare the mean amplitudes of ERPs for primed versus unprimed trials, for each response type in each group. In the visual group, the primed versus unprimed contrast was not significant for any response type: K hits ($p = .313$), R hits ($p = .279$), or CR ($p = .344$). Similarly, in the auditory group, the contrast was not significant for any response type: K hits ($p = .373$), R hits ($p = .477$), or CR ($p = .219$). The rest of main effects and interactions were not significant (Fs < .80, *p*s > .05).

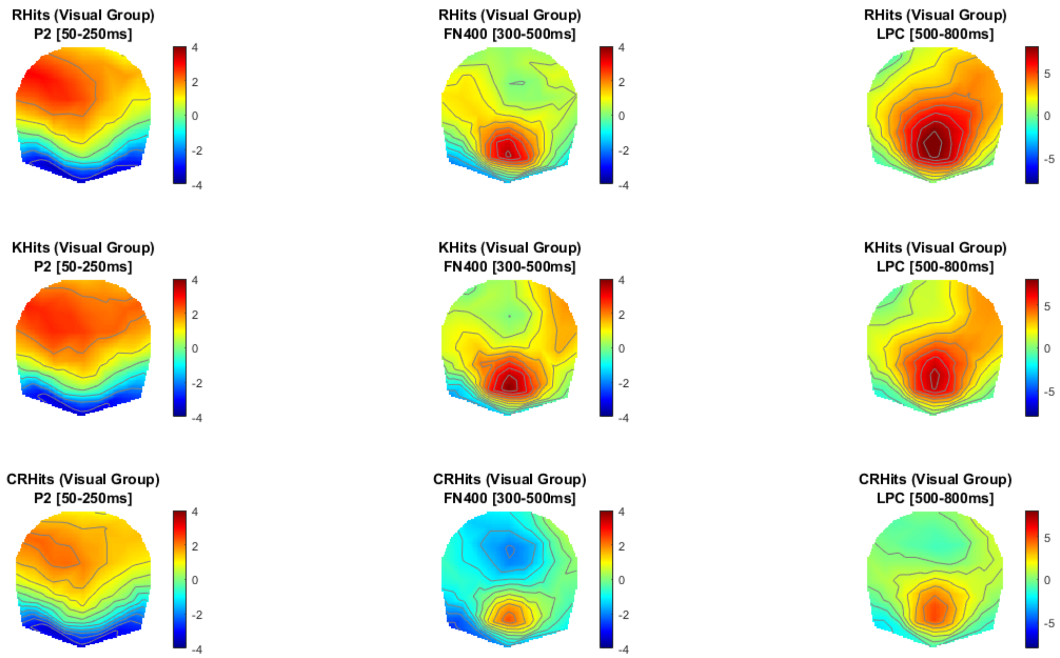


Figure 3.10. Topographical maps of the memory effects in the visual group. Images show averaged topographies of the effects over the mentioned time windows. Bars showing amplitude in uV.

Brief summary of the canonical ERP analyses. Analyses on mean amplitudes of ERPs associated with primed/unprimed K hits, R hits and CRs showed (1) expected memory effects: ERPs associated with K hits and R hits were more positive going than ERPs associated with CR in the 300-500ms time window and ERPs associated with R hits were more positive going than both ERPs associated with K hits and with CR in the 500-800ms time window; (2) expected priming effects: ERPs associated with primed words were more positive going than ERPs associated with unprimed words in the 50-250ms time window at central channels but only for CR, and the effect was significant in the visual group and only marginally significant in the auditory group; additionally, we found a priming effect on ERPs in the FN400 window at frontal channels for associated R hits and CR, but not K hits response types; (3) crucially, no significant interaction between group and priming, suggesting that these components do not necessarily capture the attribution effect. Topographical maps of the ERP memory and priming effects on each response type are shown in Figures 3.10, 3.11, 3.12, and 3.13.

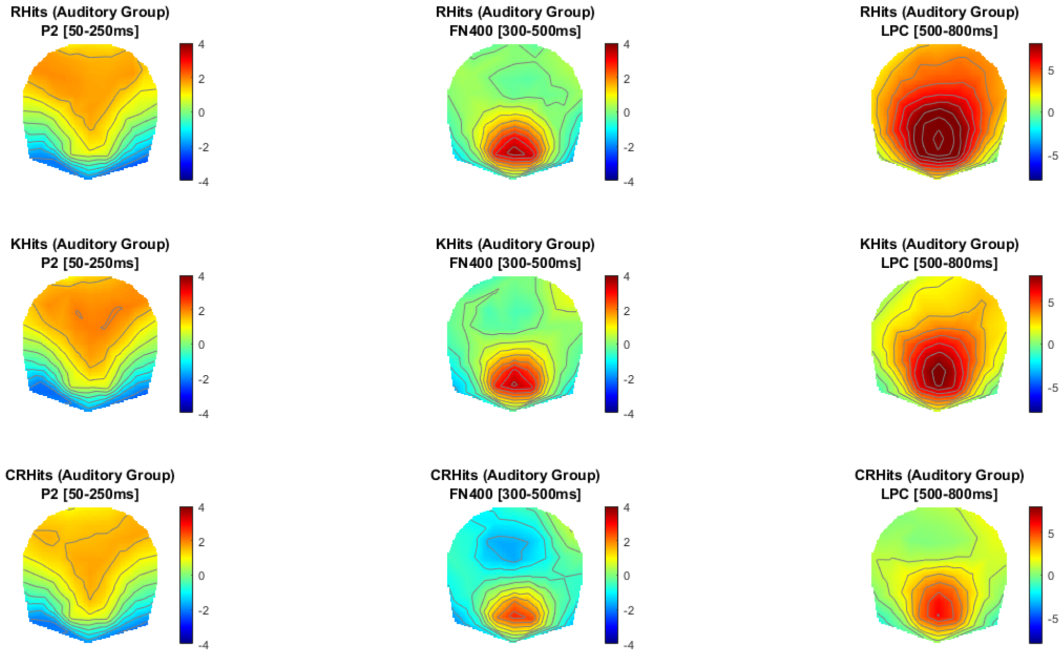


Figure 3.11. Topographical maps of the memory effects in the auditory group. Images show averaged topographies of the effects over the mentioned time windows. Bars showing amplitude in uV

3.4.3. DCM results: *Model selection.* Out of the 24 models that were specified, DCM model estimation reached convergence after 64 iterations only for 4 models (shown in Figure 3.14). Not reaching convergence after 64 iterations is an indication that these DCM models might not be appropriate for explaining the data. For this reason, we did not include in the model comparison step DCM models that did not converge. Because of this result, we could not perform family-level comparisons and only compared the 4 models that converged. Model 3 (in Figure 3.14) was the most likely from them; it includes forward and backward connections between visual areas to PRC/MTL areas, forward and backward connections between right PRC/MTL and right DLPFC, and lateral connections between the right and left PRC/MTL areas. This model was then specified and estimated in each individual participant.

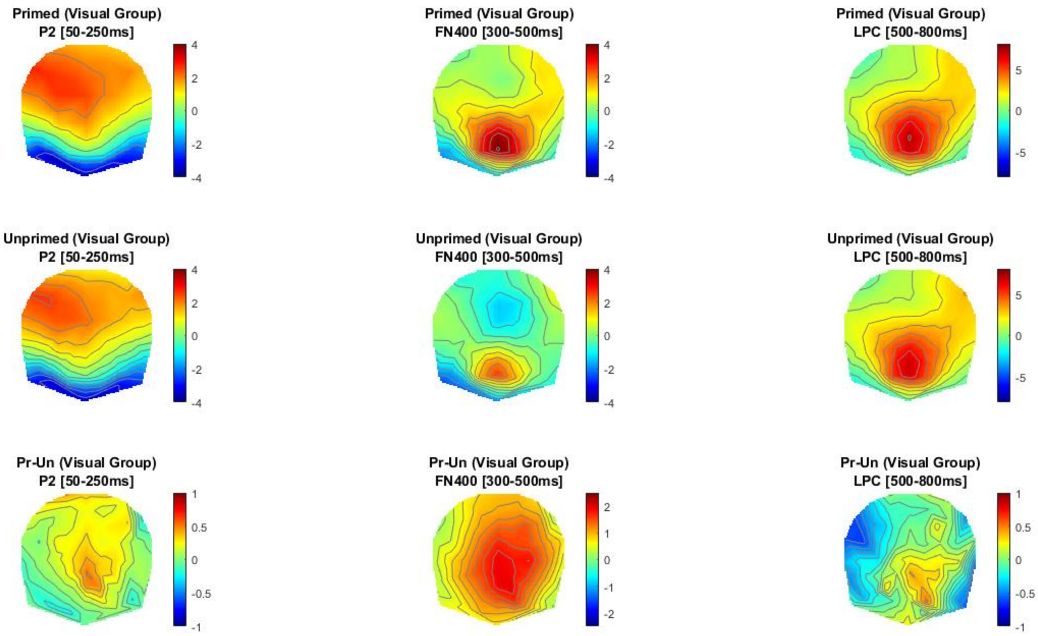


Figure 3.12. Topographical maps of the priming effects in the visual group. Images show averaged topographies of the effects over the mentioned time windows. Bars showing amplitude in uV

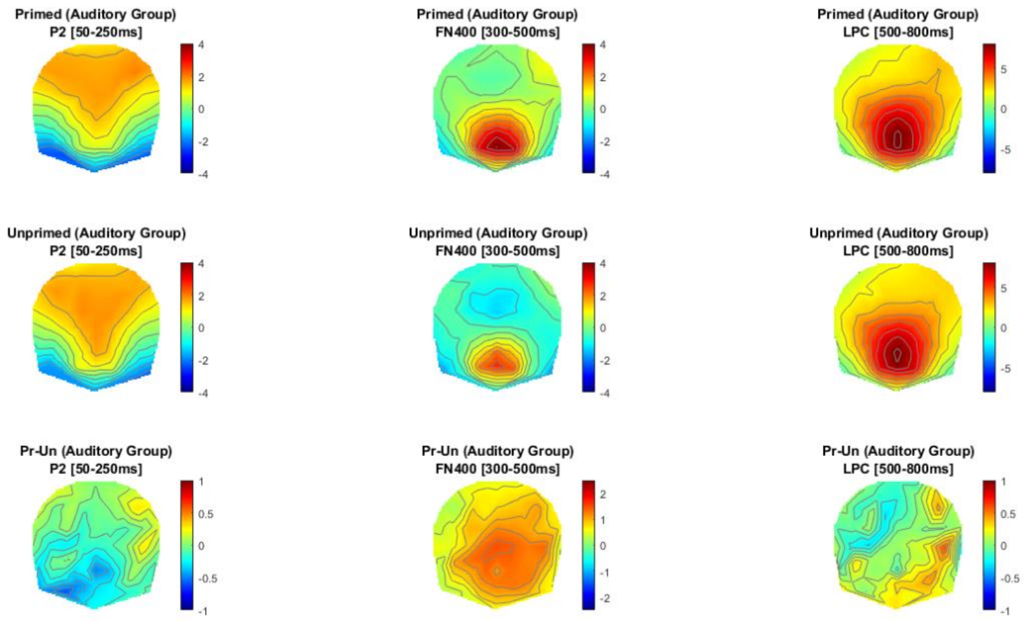


Figure 3.13. Topographical maps of the priming effects in the auditory group. Images show averaged topographies of the effects over the mentioned time windows. Bars showing amplitude in uV

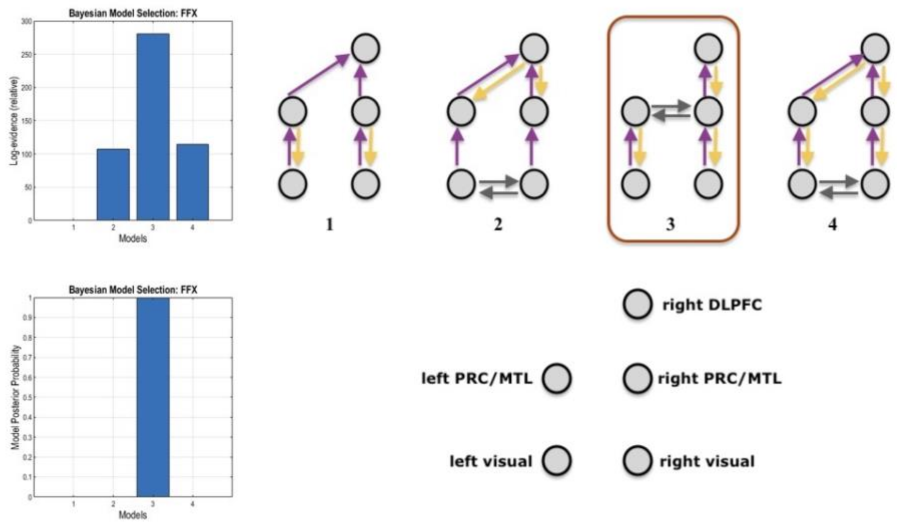


Figure 3.14. Winning DCM model. Left: log-evidence from the Bayesian model selection. Top right: the 4 models that converged. Bottom right: the ROIs included in the models. DLPFC = dorsolateral prefrontal cortex, PRC = perirhinal cortex, MTL = medial temporal lobe.

DCM results: Group differences. When estimating the model in each individual participant, for 4 participants in the visual group and 5 participants in the auditory group, it converged after 4 iterations, with values of the connectivity strength being very small (probably due to reaching a local minima). Also, for 8 participants in the visual group and 9 participants in the auditory group the estimation of the model did not reach convergence after 128 iterations. Below, separate analyses are conducted on the full sample (visual group N = 22; auditory group N = 24) and excluding these participants (visual group *N* = 10; auditory group *N* = 10).

We performed 6 independent t-tests, comparing the connectivity strength of the 6 forward and backward connections between groups. The mean parameter estimates for each connection in each group are displayed in Tables 3.4 (whole sample) and 3.5 (subsample of participants). There was a significant group difference in the connectivity strength of the forward connection between right PRC/MTL and right DLPFC (although *p* uncorrected for multiple comparisons) when performing the t-test on the whole sample of participants. The same connection showed significant group differences (even with corrected *p*) when performing the t-test on a subsample of participants (10 per group, as described above).

Table 3.4.
Mean DCM endogenous parameter estimates for all connections in the winning model

Connections	Auditory study group (*N* = 24)	Visual study group (*N* = 22)	t	*p*
Forward				
left visual → left PRC/MTL	-.081 (.395)	-.063 (.344)	.172	.864
right visual → right PRC/MTL	-.184 (.383)	-.236 (.414)	-.443	.660
right PRC/MTL → right DLPFC*	.085 (.396)	-.161 (.373)	-2.154	.037
Backward				
left PRC/MTL → left visual	-.058 (.290)	.067 (.276)	1.495	.142
right PRC/MTL → right visual	.012 (.290)	-.066 (.190)	-1.069	.291
right DLPFC → right PRC/MTL	.080 (.215)	.123 (.235)	.646	.522

Note. Two-tailed t-tests, uncorrected *p* values.

Table 3.5.

Mean DCM endogenous parameter estimates for all connections in the winning model in a subsample of participants

Connections	Auditory study group (*N* = 10)	Visual study group (*N* = 10)	t	*p*
Forward				
left visual → left PRC/MTL	-.102 (.373)	.040 (.230)	1.021	.321
right visual → right PRC/MTL	-.160 (.412)	-.380 (.313)	-1.331	.200
right PRC/MTL → right DLPFC*	.203 (.363)	-.342 (.302)	-3.653	.002
Backward				
left PRC/MTL → left visual	-.037 (.361)	.094 (.278)	.911	.374
right PRC/MTL → right visual	-.078 (.375)	-.148 (.190)	-.523	.607
right DLPFC → right PRC/MTL	.174 (.208)	.189 (.288)	.133	.896

Note. Two-tailed t-tests, uncorrected *p* values.

3.5. Discussion

The aim of this study was to investigate the mechanism of fluency attribution to memory and how it might be associated with changes in the connectivity between key brain regions involved in fluency and retrieval monitoring. Using masked repetition priming in the test phase of a recognition memory task, the experiment was designed to capture the on/off switching of the attribution system through a between-groups design. Both groups were expected to experience fluency due to masked repetition primes, but only one group was expected to use this fluency as a relevant cue for prior exposure (i.e., the study-test modality match group), whereas the other group was expected to discard this fluency in their recognition memory decisions (i.e., the study-test modality mismatch group).

Behavioural results on proportion of "old" responses confirmed our predictions: the visual study group showed significant priming effects with higher proportions of "old" responses for both studied and unstudied words, whereas the auditory study group did not show priming effects. These replicate our findings reported in Chapter 2 of the thesis, as well as Westerman et al. (2002) and Miller et al. (2008) findings. We further predicted that the priming effects will separately affect familiarity-based memory and not recollection. This, too, has been confirmed: the visual study group showed significant priming effects on familiarity false alarms, whereas the auditory group did not show priming on K responses.

Although not of central interest, we also found a group difference in memory performance, with visual study group having increased accuracy compared to the auditory study group. According to the transfer appropriate processing theory, memory success depends on the match between the type of processing engaged at study and at test (Morris, Bransford & Franks, 1977). Considering that the visual group studied the words in the same modality they received the memory test could have led to enhanced memory performance.

Results of the ERP canonical analysis showed priming effects in the P2 time window (50-250ms) at central sites, with ERPs associated with primed CRs more positive going than ERPs associated with unprimed CRs in both groups (although only marginally significant in the auditory group); note, however, that these effects were not very strong and only appeared in planned contrasts and not in the main ANOVA. Also, there were priming effects in the FN400 (300-500ms) at frontal sites, with more positive going ERPs for primed R hits and CRs than unprimed R hits and CRs, respectively. Importantly, there were no interactions between group and priming in any of the time windows of interest, thus there was no evidence that these components' priming effects differed between groups.

We also found basic ERP memory effects: old/new effects at frontal (FN400) and parietal (LPC) channels in both groups. In the 300-500ms time window following target onset, ERPs associated with K hits and R hits were more positive going than ERPs associated with CRs; and in the 500-800ms time window, ERPs associated with R hits were more positive going than ERPs associated with K hits and CRs, for both groups. These findings replicate consistently reported old/new and R/K ERP effects (Rugg & Curran, 2007). But more importantly, there were no group differences for any of these effects, suggesting that the canonical component analysis did not capture the attribution process, which should have been present in the visual but not in the auditory group. This suggests that fluency attribution to memory does not simply modulate the amplitude of memory- and priming-sensitive components.

The DCM analysis first indicated that at the group level, from the estimated models, the most likely to explain the data had forward and backward connections between input visual areas and PRC cortices, and between right PRC and right lateral prefrontal cortex. Furthermore, after the model was estimated in each individual, participants in the study-test modality mismatch group showed stronger connectivity strength of the forward connection between right PRC and right DLPFC. In another DCM study on evoked responses (although using an entirely different paradigm to ours), Garrido et al. (2009) found that repetition suppression in A1 was associated with a decrease in the connectivity strength of the forward connection from A1 (primary auditory cortex) to STG (superior temporal gyrus). This offers an explanation of how our group difference in the strength of the forward connection between right PRC to right DLPFC can be interpreted. It indicates that within the DCM for evoked responses framework repetition suppression is reflected in a decrease in the strength of a (forward) connection originating from a region which is expected to respond to repetition of a stimulus (i.e., PRC in our case). Our results showed that participants in the visual group had a significantly weaker connection from the right PRC to right DLPFC compared to the auditory group. As suggested by the lack of group differences in ERP priming effects, we can assume that both groups showed repetition suppression at the PRC level, however the coupling between PRC and DLPFC seems to be different depending on whether fluency is relevant for prior exposure or not. It could be inferred that when study and test modalities do not match, the switching off of the attribution system might be indicated by a change in the connectivity between a brain region that expresses fluency and a brain region involved in familiarity-based memory/retrieval monitoring (i.e., right PRC and right DLPFC, respectively).

Implications of these results. Our behavioural results replicate previous findings (Miller et al., 2008 and Westerman et al., 2002; Chapter 2 of this thesis) showing that study-test modality match makes visual fluency during memory test irrelevant to be used as evidence for prior exposure, when participants studied the words auditorily. By replicating our findings in the Chapter 2 experiment, we provide further support for the use of study-test cycles to investigate fluency attribution to memory in terms of underlying neural mechanisms, since it allows the increase of number of trials (compared to Westerman et al., 2002, for instance). Our canonical ERP analysis replicated consistently reported old/new effects at frontal (in the 300-500ms time window) and R/K effects at parietal (in the 500-800ms time window) sites (Rugg & Curran, 2007). We found ERP priming effects in the 300-500ms time window and in an early P2-like time window (Woollams et al., 2008). Finally, our DCM analysis showed group differences in terms of the connectivity strength of the connection from the right PRC to the right DLPFC. To our knowledge this is the first study to show a link between switching off (non-mnemonic) fluency attribution to memory (in the study-test modality mismatch group) and increased connectivity between right PRC and right DLPFC. The group differences we observed are at the neural system level (i.e., in the extrinsic forward connection between the two brain regions), and not modulated by fluent/non-fluent (i.e., primed/unprimed) trials. This differentiates the present study from fMRI connectivity results looking at fluent versus non-fluent trials (Dew & Cabeza, 2013; Gomes et al., 2019).

Methodological considerations. Although the DCM approach offers a way to study effective connectivity, there is no clear objective way to quantify the likelihood of a model to explain the data; it can only be inferred that a model is best explaining the data among the group of models that were compared. Nonetheless, the brain regions we included in the models have been associated with a similar task in previous research (e.g., Dew & Cabeza, 2013; Gomes et al., 2017). PRC activity reduction was associated with perceived oldness (Daselaar et al., 2006; Gonsalves et al., 2005) and familiarity-based decisions in particular (Eichenbaum, Yonelinas & Ranganath, 2007). However, Kafkas and Montaldi (2014) found PRC to be associated with reported novelty, rather than familiarity, with increasing PRC activity positively correlated with novelty strength. Also based on Dew and Cabeza's (2013) findings that the PRC activity is suppressed for fluent versus non-fluent stimuli, research seems to suggest that the function of PRC is related to fluency (which can potentially be interpreted as a lack of novelty perception). The other area we included in the DCM models was the right dorsolateral PFC, which has been connected with retrieval monitoring (Fletcher & Henson, 2001) and familiarity-based memory decisions in particular (Dobbins et al., 2003; Henson et al., 1999).

In our experiment, participants did not make enough false alarms to be able to estimate ERPs for primed versus unprimed false alarms. One reason for this could be the relatively deep encoding: when participants have to make interestingness judgments, they might think about the meaning of the word rather than superficial features. Future research can use a similar way to manipulate the switching on/off of fluency attribution to memory, but with a shallow encoding in order to increase the proportion of false alarms. This would allow the investigation of fluency misattribution to memory at a trial level.

Conclusion. The present study investigated how diminished reliance on fluency originating from a non-mnemonic source (i.e., priming) in memory decision is associated with changes in connectivity between brain areas involved in fluency tracking and retrieval monitoring processes. We showed (1) group differences in terms of fluency attributions to memory due to a change in modality at test, with participants who studied the words auditorily not using visual fluency induced through priming in their memory decisions; (2) no group differences in terms of ERP priming effects in the FN400 time window or in terms of ERP memory effects; (3) group differences in the connectivity strength of the connection between right PRC and right DLPFC, with stronger connectivity in the study-test modality mismatch group. This indicates that, at the neural system level, a lack of reliance of non-mnemonic fluency for memory decisions seems to be reflected into a stronger connectivity strength between right PRC and right DLPFC.

Chapter 4: Conceptual priming of recognition memory: conceptual fluency or encoding context reactivation?

Abstract

Recent studies reported short-term conceptual priming effects on recollection, with primed studied words receiving more 'remember' responses compared to unprimed studied words. We propose that an encoding context reactivation account could explain conceptual priming effects on recollection, with primes reactivating (part of) the encoded semantic context; however, no direct evidence has been found for this account, given that the encoding context has not been controlled for. The present study investigated the mechanism of conceptual priming effects on recollection. In Experiment 1 we biased the encoded context of a set of target words, and in Experiments 2, 3 and 4, we used homonyms and biased the encoded meaning by pairing them with another word (related to one of the homonym's meanings) in the study phase. In the test phase of all four experiments, the target words were preceded by three types of masked primes: related to the encoded meaning/context, related to a different meaning/context, or unrelated, and participants made an old/new judgment and then a familiar/remember judgment. If the conceptual priming effects are due to increasing *item (conceptual) fluency* then we would expect both types of related primes to increase familiarity/recollection compared to unrelated primes. If the conceptual priming effects are due to a (partial) retrieval of the encoded semantic context, then we would expect that only primes related to the encoded meaning/context would increase recollection compared to the other priming conditions. In Experiment 1 we found no significant conceptual priming effects. In Experiment 2, with homonym targets, same meaning primes increased correct recollection compared to both primes related to a different meaning and to unrelated primes. In Experiment 3, also with homonym targets, there was a trend for same meaning primes to increase recollection compared to different meaning, whereas the reverse was observed for familiarity responses. In Experiment 4, whether related primes were related to the encoded context or not was manipulated between groups; there were no conceptual priming effects on recollection, but different meaning primes increased familiarity compared to unrelated primes when homonyms were encoded with their subordinate meaning. Overall, priming effects on recollection were subtle and less consistent than predicted; nonetheless, the patterns of results favoured the encoding context reactivation rather than the item conceptual fluency one. Priming effects on familiarity, in contrast, were in line with the item fluency account.

4.2. General Introduction

Recognition memory judgments can be influenced through the use of short-term masked priming of the test stimuli (i.e., by briefly preceding the test stimuli with their own presentation or a related stimulus). Recollection, conceptualised as the kind of recognition memory where a present stimulus triggers the retrieval of further details about its previous encounter(s) (e.g., Migo et al., 2012), can be influenced by masked conceptual priming (e.g., Li et al., 2017; Taylor & Henson, 2012; Taylor & Henson, 2013; Wang et al., 2015). Briefly preceding the target words with masked conceptually related primes increases the likelihood that participants will remember them, potentially by offering an additional cue that helps them to partially retrieve the encoded event (Taylor & Henson, 2012). The specific mechanism by which masked conceptual primes influence recollection remains an open question that we aimed to investigate in this paper.

Increasing perceptual fluency of test words through short-term masked repetition priming leads to higher proportions of 'old' or 'familiar' responses for primed versus unprimed stimuli, regardless of the study status of the words (e.g., Jacoby & Whitehouse, 1989; Rajaram, 1993; Taylor & Henson, 2012; Woollams et al., 2008). Familiarity refers to the feeling of having been exposed in the past to a present stimulus, in the absence of any details related to the previous encounter(s) (Migo et al., 2012). Repetition priming effects on familiarity have been replicated in multiple studies and there is a level of consensus regarding the underlying mechanism: primed stimuli are processed faster or more *fluently* than unprimed stimuli and this perceptual fluency is attributed to prior exposure (e.g., Jacoby & Whitehouse, 1989). Importantly, when distinguishing between familiarity and recollection, it has been consistently found that repetition priming selectively increases familiarity of both studied and unstudied stimuli (e.g., Rajaram, 1993; Taylor & Henson, 2012; Taylor et al., 2013). This indicates that (1) repetition priming influences recognition memory decisions when they are based on a "feeling" of having been presented with the item before rather than a retrieval of additional details about the item and (2) that repetition priming effects are independent of whether the item has been studied.

The effects of conceptual priming on recognition memory are less clear in terms of the kind of recognition memory conceptual primes increase, and this is driven by differences in how the prime-target "conceptual" relation is operationalised. There is a series of studies where preceding the targets with conceptually related words (e.g., table – CHAIR) led to similar effects as repetition priming: a higher proportion of 'old' or 'familiar' responses for both studied and unstudied words (Dew & Cabeza, 2013; Kurilla, 2011; Kurilla & Westerman, 2008; Rajaram & Geraci, 2000). In these studies, the primes and target words have high lexical association probabilities (Dew & Cabeza, 2013; Rajaram & Geraci, 2000), so this is perhaps more appropriately labelled as *associative priming*. Having high lexical association probabilities between the prime and the target means, by definition, that the target is very likely to come to mind given the prime. Therefore, upon processing the masked associative prime, participants are likely to generate the target before it appears on the screen, which effectively creates conditions similar to repetition priming. It is perhaps unsurprising, then, that the effects of associative priming are similar to those of repetition priming (i.e., increased familiarity), and they presumably also rely on an increase in test item fluency being (mis)attributed to memory (see middle row of Figure 1.2).

Another series of studies investigated masked priming effects on recognition memory using "pure" conceptual priming (as opposed to *associative priming*). In these studies, crucially, the primes were specifically chosen to not be lexically associated with the target words they preceded (Taylor & Henson, 2012; Taylor et al., 2013; Wang et al., 2015; Li et al., 2017); this type of priming will be hereafter referred to as *conceptual priming*. These studies found that conceptual priming of test words increased the proportion of recollection responses for studied words only, with no effect on false alarms. The lack of effects on false alarms suggests that the effect of conceptual primes in these studies is not due to misattribution of fluency to memory. Also, it suggests that when conceptual primes affect recollection, they (at least partially) reactivate the encoded context, since recollection entails retrieval of details of the encoding episode. The proposed explanation is the so-called 'partial recollection' framework: the authors argued that processing of non-associative conceptual primes increases recollection, by reactivating the spontaneously generated semantic context at study (Taylor & Henson, 2012). Given the experimental context where participants study the words presented on a simple background that does not change from word to word, and in the absence of a rich external context, the episodic memory trace is likely exclusively based on participants' internal context (i.e., the concepts they spontaneously generate while responding to the word). This is why the pair formed by the prime and the target might be a better retrieval cue that the target word alone. An fMRI study by Taylor et al. (2013) found a correlation between the behavioural conceptual priming effect on recollection and the conceptual priming effect on the BOLD response in brain regions associated with recollection, providing some support for the suggested 'partial recollection' explanation. This explanation aligns with Ratcliff and McKoon's (1988) retrieval theory of priming, where a conceptual prime and the target it precedes form a compound cue which is then used to search the long-term memory for an encoded trace. Thus, rather than "pre-activating" the target itself, we proposed that conceptual primes form a compound cue with the target, and this facilitates participants' access to the encoded context, leading to recollection.

The present paper aims to investigate the effect of conceptual priming on recollection, more specifically, by testing *the encoding context reactivation account* according to which conceptual primes act as partial retrieval cues for the encoded memory trace created in the study phase. Although we do not predict this to be the case, we will be able to test whether conceptual priming effects observed on recollection can be explained through *the item conceptual fluency account* according to which conceptual primes increase conceptual fluency of test items which in turn is attributed to memory in a similar fashion as fluency induced by repetition primes. Thus, the main research question explored in the paper is: **Does conceptual priming of recognition memory test cues increase recollection by triggering a partial retrieval of the encoded context or is the priming effect observed on recollection due to an increase in conceptual fluency?**

The proposed encoding context reactivation account of the conceptual priming effect is based on the assumption that conceptual primes during test reactivate spontaneously generated concepts participants activated during encoding, in this way acting like retrieval cues (additional to that target word itself). Although this is a plausible explanation, it is unknown what, if any, related concepts participants spontaneously generated when making interestingness judgments during the study phase. In addition, the item conceptual fluency account is rejected mainly based on the lack of a conceptual priming effect on false alarms (in contrast to the repetition priming effect on familiarity false alarms). It is noteworthy that participants do not generally make many 'remember' false alarms in experiments using the R/K paradigm in a similar fashion, so the conceptual fluency explanation cannot necessarily be rejected based on the lack of 'remember' false alarms alone.

The present study aimed to investigate the effects of non-associative, masked conceptual primes on recognition memory, while encouraging the activation of specific semantic information at study and then using conceptually related primes to either activate the same or a different semantic context at test. We did so by pairing each target word of interest in the study phase with another word related to a specific context of the target. During the test phase, conceptual primes were related to the encoded context of the target word (same context priming condition), related to a different context of the target (different context priming condition), or unrelated to the word (unrelated priming condition). Because the first two types of primes are both conceptually related to the target word, they should both increase item conceptual fluency. Therefore, on the item conceptual fluency account, recollection/familiarity should be increased in both the same context and the different context priming conditions relative to the unrelated priming condition. However, according to the encoded context reactivation account, only same context priming should increase correct recollection, on the premise that it reactivates the concepts generated during encoding.

Roadmap of the paper: The research question was investigated through a series of four experiments: in Experiment 1 we biased the encoded context (e.g., for SUIT, we used context words "tailor" and "swimming"), predicting that when participants encode the target word in one context (tailor – SUIT), conceptual primes related to that specific context (formal – SUIT) and not conceptual primes related to a different context (pool – SUIT) will increase recollection compared to unrelated primes. The same general approach was used in Experiments 2, 3, and 4, except that the target words were homonyms (i.e., words with two different meanings). In these three experiments, we biased the encoded meaning of the target words (e.g., for the homonym BARK, we used context words "tree" and "howl", one for each meaning of the word), predicting that when participants encode one meaning of the homonym (tree – BARK), conceptual primes related to that meaning (trunk – BARK) and not conceptual primes related to the different meaning (snarl – BARK) will increase recollection compared to unrelated primes.

4.3. General methods

Design. The dependent variables were the proportion of familiarity and recollection hits in each experimental condition, as will be specified for each experiment. Experiments 1-3 were conducted as repeated measures designs with prime type as the within-participants factor with three levels: same context/meaning (i.e., the prime used was conceptually related to the target and related to the encoded context/meaning), different context/meaning (i.e., the prime used was conceptually related to the target, but related to a different context/meaning than the one encoded), unrelated (i.e., the prime was conceptually unrelated to the target). Experiment 4 was conducted as a between-groups design, with the levels of the prime type factor being different: in one group same meaning primes and unrelated primes, in the other group different meaning primes and unrelated primes.

Participants. All participants in this study were British English native speakers, students at the University of Manchester and reported to be in good neurological health with normal or corrected-to-normal vision. They were tested individually in a testing cubicle and received either Psychology course credits or financial compensation for their participation. For 85% power to detect a medium-sized effect size (i.e., a Cohen's d equal to 0.5), the target sample size was 31. This was rounded up based on the particular counterbalancing scheme of each experiment. As exclusion criteria, we used the proportions of recollection false alarms, given that participants who understand the task do not make many recollection false alarms. The interquartile range (IQR = quartile 3 – quartile 1) was calculated and participants who made more than Q3 (quartile 3) + 1.5*IQR recollection false alarms in each experiment, were excluded.

Procedure. Participants were given a brief explanation about the experiment (see Supplementary materials for specific R/K instructions) and then completed a short practice block consisting of a short study list (6 study trials), the distracting task and a short test list (12 test trials that were not preceded by primes. After this, the experimenter checked whether participants understood the difference between 'familiar' and 'remember' options (i.e., familiarity/recollection). Depending on their responses, the instructions were given again with a tailored amount of details. Once this distinction was clear for participants, they started the actual experiment.

There were 3 cycles of study, distraction, and test blocks in Experiments 1 and 2, and 4 cycles in Experiments 3 and 4. In the study phase, participants viewed word pairs and made relatedness judgments about them by button press, using their dominant hand. The encoding task was slightly different in Experiments 1 and 2 compared to Experiments 3 and 4, as will be described later, in each experiment’s procedure section. In the distraction phase, participants were given a 3-digit number and asked to count backwards from that number by 3s for 30 seconds. In the test phase, the presentation of words (except the first 10 trials) was preceded by primes displayed on the screen for 50ms, sandwiched between a 500-ms forward mask and a 50-ms backward mask. Participants’ memory for the studied words was tested using a modified version of the R/K paradigm (Tulving, 1985) in which we replaced ‘know’ with ‘familiar’. Throughout the paper, ‘familiar’ responses will be referred to as K (i.e., the proportion of ‘familiar’ responses) or iK (calculated as iK = K/(1-R), where R is the proportion of ‘remember’ responses; Yonelinas & Jacoby, 1995), and ‘remember’ responses will be referred to as R. Participants were presented with one word at a time on the screen (half were studied words and half unstudied) and they had to first indicate whether the word was old or new (i.e., presented in the study phase or not). They had a time limit of 2 seconds for this judgment, after which their responses were not recorded, and the next trial was presented. For words they judged as ‘old’, they had to indicate if they ‘remember’ the word from the study phase or if it seemed ‘familiar’. This judgment also had a time limit of 2 seconds after which their responses were not recorded, and the next trial appeared on the screen.

Following the completion of the experiment, a ‘prime awareness check’ was conducted: in Experiments 1 and 2 participants were asked *whether they noticed the hidden words during the experiment*, and in Experiments 3 and 4 they were asked *whether they noticed something unusual during the experiment*. Participants’ responses were coded as follows: 1 – unaware, 2 – aware of something being flashed but not able to read the prime words, 3 – aware of the prime words, 4 – aware of the prime words and aware that sometimes they were related to the target words they preceded.

Statistical analyses. All reported analyses on proportions of responses are based on the studied target words. We were mainly interested to test the encoding context reactivation account, and because the types of conceptually related primes were directly connected to the encoded context, we did not analyse false alarms. Also, we did not perform analyses on response times due to the low number of trials per condition (~30 trials overall to which participants responded ‘familiar’, ‘remember’ or ‘new’, resulting in many participants with <10 trials in at least one condition). Before running statistical analyses of the data, trials were excluded when participants did not make an ‘old/new’ judgment or if they missed the 'R/K' judgment after answering 'old'. In Experiments 1-3, we performed repeated-measures ANOVAs with priming as within-subjects factor (3 levels: same context/meaning prime, different context/meaning prime, unrelated prime), and in Experiment 4, we performed mixed 2 (group: same meaning/different meaning) x 2 (prime type: related/unrelated) ANOVAs separately on R hits and iK hits. In line with the encoding context reactivation account of previously reported conceptual priming effects on recognition memory, we expected the encoded context to matter for priming effects on recollection. Planned contrasts were performed on the proportion of R responses in order to compare the priming conditions: in Experiments 1-3: same context/meaning priming versus different context/meaning priming, same context/meaning versus unrelated priming, and different context/meaning priming versus unrelated priming; in Experiment 4: same meaning priming versus unrelated priming and different meaning priming versus unrelated priming. We predicted that the proportion of R responses will be higher for target words preceded by same context/meaning primes compared to the other priming conditions. We did not have specific predictions for conceptual priming effects on familiarity responses. We also expected the different context priming condition to be similar to the unrelated priming condition. However, if conceptual fluency drives recollection judgments, both same- and different-context/meaning primes should increase the proportion of R responses compared to unrelated primes. A .05 significance threshold was used for all analyses. All t-tests reported are two-tailed unless specified otherwise.

4.4.1. Experiment 1

The aim of Experiment 1 was to investigate whether conceptual priming effects on recollection can be related to a match between the encoding and the test context. The crucial question was whether it matters if the conceptual prime is related to the context activated at study. If item fluency per se is all that matters, any conceptually-related prime should increase recollection compared to unrelated primes. However, if relatedness to the encoding context matters, then priming should only occur for related primes that are also related to the encoding context. This was done by manipulating the context in which participants encoded the target words in the study phase (e.g., fabric – WRINKLES) and then using conceptual primes that were either related to the encoded context (e.g., smooth – WRINKLES) or a different context (e.g., elderly – WRINKLES) in the test phase. Barclay et al. (1974) showed how encoding contexts can influence the interpretation of words. In a series of cued recall experiments, they found that recall cues congruent with the encoded context of words were more effective than non-congruent cues in increasing participants' memory performance. For instance, the internal representation of the word *ink* changes if presented with (1) "The student picked up the ink." versus (2) "The student spilled the ink." at study; in turn, a cue like "something in a bottle" works better for remembering the word *ink* presented in the study context (1) compared to "something that can be messy", which would work better for remembering the representation of the word created in the study context (2). In the present experiment, by pairing the target words with another word during encoding, we expected participants to activate a specific semantic context for the target that we can then prime during test. The different context prime was conceptually related to the word but to a different context than the studied one; priming a different semantic context was not expected to affect recognition memory judgments compared to unrelated primes. Thus, our hypothesis, consistent with the encoded context reactivation account, was that only primes related to the encoded context, and not those related to a different context, would increase recollection hits relative to unrelated primes. If, however, the item fluency account is the explanatory mechanism of conceptual priming of recognition memory, then both same context- and different context conceptual primes should increase recollection compared to unrelated primes.

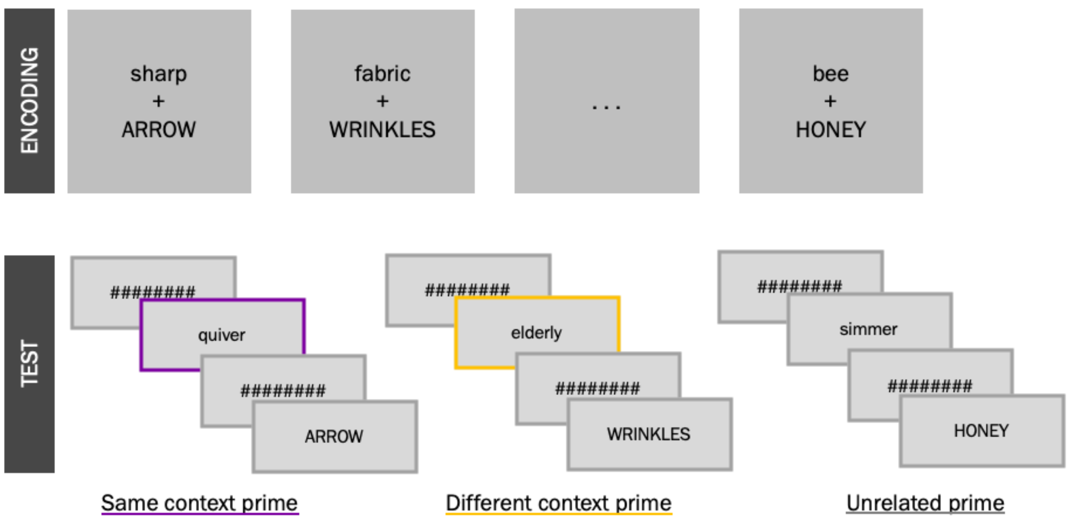


Figure 4.1. Priming conditions used in Experiment 1

4.4.2. Methods

Participants. The target sample size of Experiment 1 was 35[2]. Four participants were excluded from further analysis based on the IQR-based method (see Supplementary materials for a histogram). Data from 31 participants (mean age = 23.77, SD = 4.74 years, 18 female) were included in the analyses.

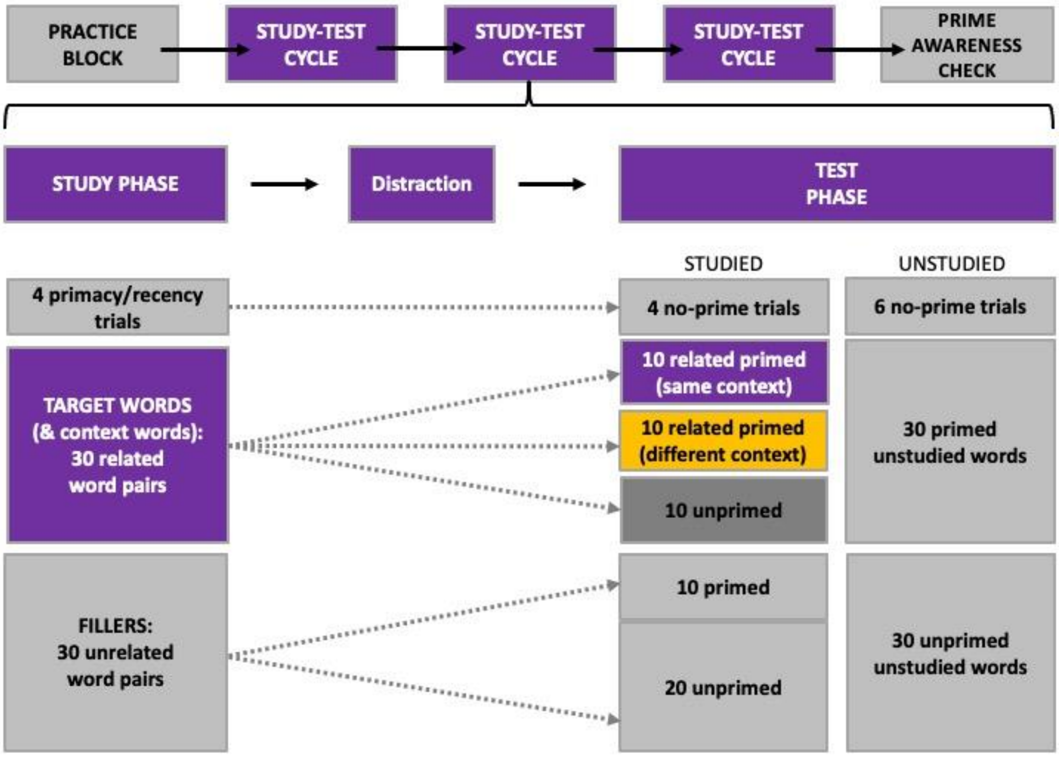


Figure 4.2. Experiment 1 design showing the overall structure of the experiment (top row) and what a study-test cycle consisted of (under the curly bracket). The colours are symbolic, for display purposes only; during the experiment, the screen was grey. Also, the trial order was randomised in the experiment, for ease of interpretation the trials are shown sorted in the figure.

Stimuli. For each of the 90 target words, 2 semantic contexts were generated, and for each context, 2 context/prime words were generated. For example, for the target 'WRINKLES', the contexts were skin-related, with context/prime words 'elderly' and 'senior', and clothing-related, with context/prime words 'fabric' and 'smooth' (see full list in see Supplementary materials). Target words were selected from the set of stimuli used in Taylor and Henson (2012). All target words, context words and primes were between 3 and 9 letters long and had written frequencies between 1 and 150 per million (target words: length M =

[2] Data collected from the first 13 participants were not usable due to a technical error and they were replaced.

5.24 (SD = 1.30), frequency M = 36.66 (SD = 37.59); context words: length M = 6.34 (SD = 1.66), frequency M = 31.80 (SD = 35.07); primes: length M = 5.66 (SD = 1.56), frequency M = 32.11 (SD = 35.42) occurrences per million words, based on CELEX (Medler & Binder, 2006)). Importantly, the primes were not lexically associated with the target words they preceded, having forward and backward association probabilities <.10 in the USF norms (Nelson, McEvoy & Schreiber, 1998).

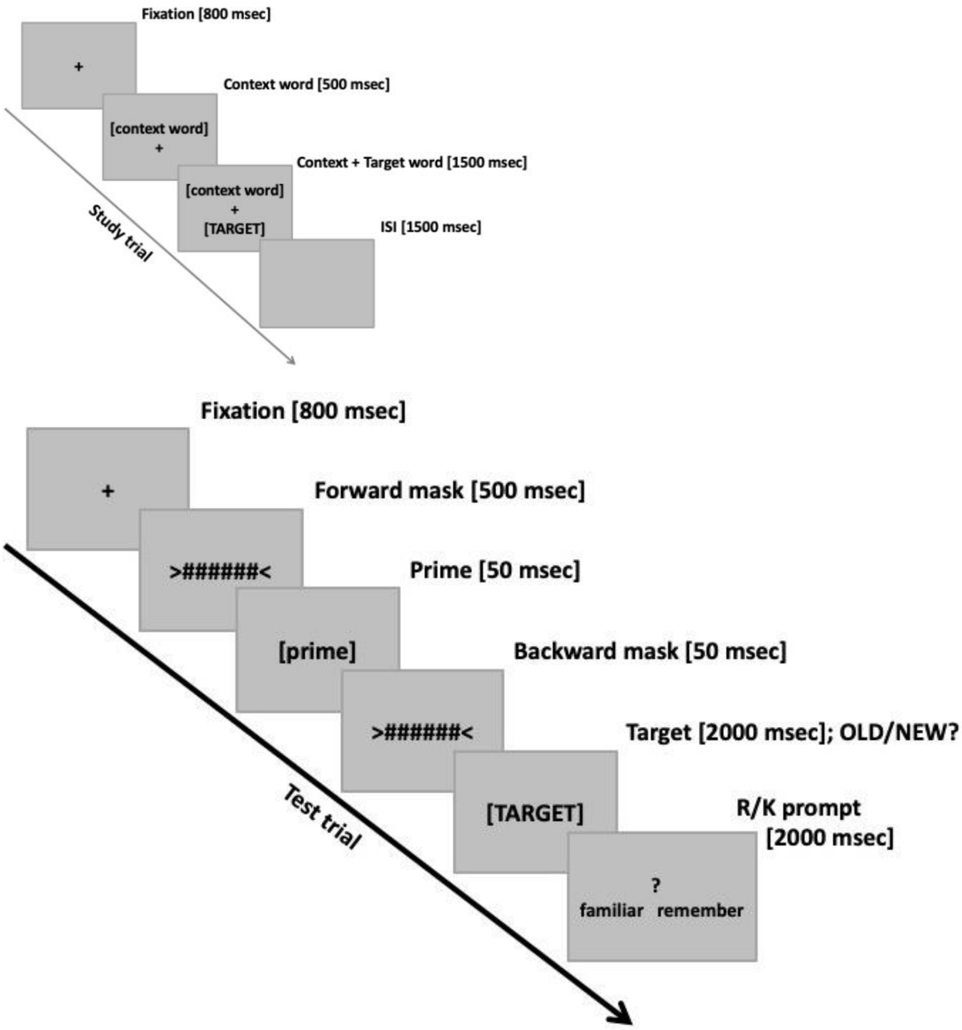


Figure 4.3. Schematic representation of trials during the study phase (top) and during the test phase (bottom) of the experiment.

The 90 target words were presented in one of the following conditions: same context priming, different context priming, unrelated priming; this was counterbalanced across participants. In addition to the stimuli of interest, we used 480 non-critical 'filler' words with similar word length and written frequencies as the stimuli of interest (see Figure 4.2, dark grey boxes). Fillers presented in the study phase were always paired with unrelated context words.

Procedure

In the study phase (64 trials, 30 of which contained critical targets; see Figure 3), participants viewed word pairs and indicated whether they were related or not. The critical targets were always presented with a related context word.

4.4.3. Results

Table 4.1.

Memory performance across the four experiments

	Experiment 1	Experiment 2	Experiment 3	Experiment 4	
				Same meaning group	Different meaning group
Overall Hits – FAs	0.61 (0.13)	0.51 (0.15)	0.51 (0.16)	0.58 (0.13)	0.63 (0.11)
R Hits – R FAs	0.48 (0.18)	0.44 (0.20)	0.31 (0.18)	0.33 (0.15)	0.41 (0.16)
K Hits – K FAs	0.13 (0.10)	0.09 (0.15)	0.17 (0.13)	0.23 (0.13)	0.20 (0.14)

Note. The proportion of responses shown in the table were calculated across all trials, not only for the stimuli of interest, which was only a subset of the whole dataset. Standard deviations in parentheses. FA = false alarms, R = proportion of 'remember' responses, K = proportion of 'familiar' responses.

Table 4.2.

Mean proportions of responses across the four experiments

	Experiment 1			Experiment 2			Experiment 3			Experiment 4			
										Same meaning group		Different meaning group	
	Same context prime	Different context prime	Unrelated prime	Same meaning prime	Different meaning prime	Unrelated prime	Same meaning prime	Different meaning prime	Unrelated prime	Related prime	Unrelated prime	Related prime	Unrelated prime
R	0.49 (0.19)	0.50 (0.20)	0.48 (0.20)	0.50 (0.22)	0.43 (0.23)	0.45 (0.21)	0.33 (0.19)	0.30 (0.18)	0.32 (0.21)	0.34 (0.16)	0.34 (0.16)	0.41 (0.17)	0.41 (0.16)
iK	0.47 (0.19)	0.44 (0.17)	0.44 (0.20)	0.39 (0.18)	0.39 (0.17)	0.42 (0.18)	0.33 (0.17)	0.39 (0.20)	0.36 (0.19)	0.49 (0.17)	0.45 (0.16)	0.45 (0.17)	0.45 (0.19)
New	0.26 (0.13)	0.28 (0.14)	0.29 (0.15)	0.31 (0.15)	0.35 (0.17)	0.33 (0.17)	0.45 (0.16)	0.43 (0.18)	0.44 (0.20)	0.35 (0.17)	0.37 (0.15)	0.32 (0.13)	0.32 (0.13)

Note. Standard deviations in parentheses. The proportions of responses shown in the table are to the target studied words only, that were given 'remember' (R), 'familiar' (iK) or 'New' responses for each Priming condition. (iK – independent familiarity, calculated as K/(1-R) (Yonelinas & Jacoby, 1995)

Memory performance was above chance for both K and R responses ($p < .001$ when comparing both K Hits – K FAs and R Hits – R FAs with zero) (see Table 4.1). Mean proportions of 'remember' (R) and 'familiar' (iK) responses for each condition are presented in Table 4.2 and Figure 4.4. Because we expected priming to selectively affect recollection, the proportion of familiarity responses inferred from K responses could have been "artificially" affected by priming as well. Thus, we calculated familiarity under independence assumptions, as iK = K/(1-R) (Yonelinas & Jacoby, 1995).

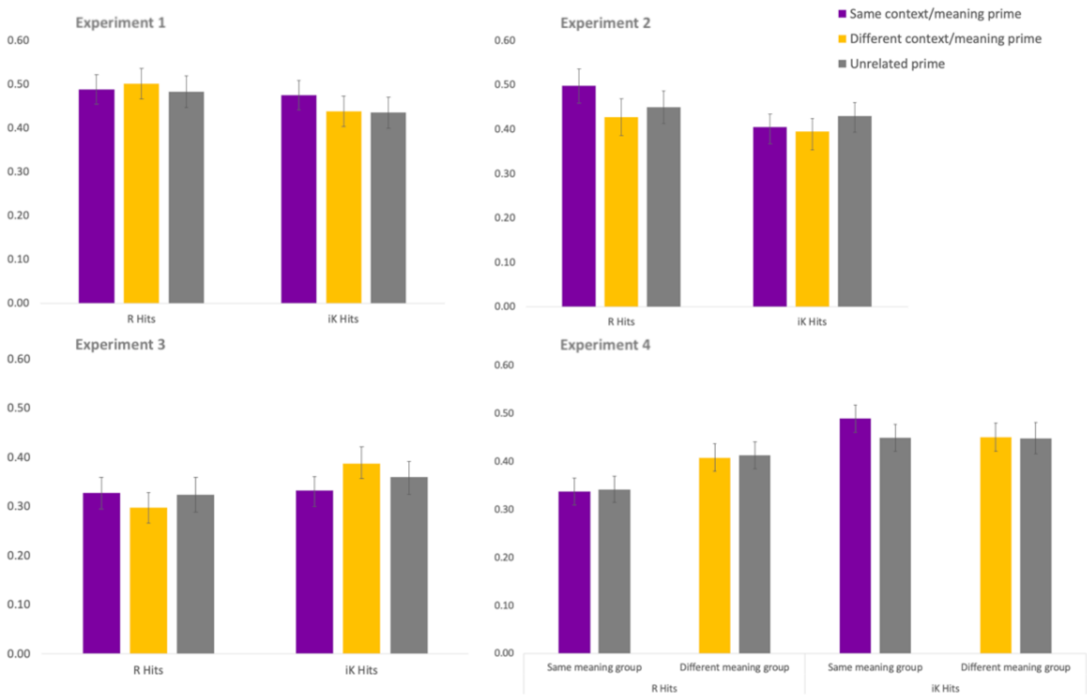


Figure 4.4. Proportions of R and iK responses across the four experiments, in each priming condition for studied words only. Standard error bars.

There was no significant main effect of priming on R Hits, as shown by the repeated-measures ANOVA on R Hits (F(2,60) = .31, p = .732, partial η^2 = .010). Similarly, the ANOVA on iK Hits did not yield a significant main effect of priming (F(2,60) = .73, p = .484, partial η^2 = .024).

The encoding task required participants to decide whether the words in each pair were conceptually related or not. The 90 targets were always paired with context words that were conceptually related (as determined by the researchers) in the encoding phase. On average, participants responded "related" for 80% of the encoding trials of interest consisting of target words and their related context words (SD = 8.61, min = 57.78% and max = 90%), which validated this aspect of our design. However, because participants did not find all targets related to their context words, it could be the case that they did not encode the words in the intended context, and this could have affected the likelihood to observe priming effects. In order to remove the potential confounding effect of this, a separate set of analyses was performed after excluding trials participants did not find related, as intended (see Supplementary Materials for the data). The ANOVA on R Hits did not show any significant priming effects (F(2,60) = .45, p = .643, partial η^2 = .015); and neither did the ANOVA on iK Hits (F(2,60) = .65, p = .525, partial η^2 = .021).

In terms of prime awareness, 16 participants were unaware, 5 participants were aware of something briefly flashed, 3 participants could read the words and 7 participants were aware that sometimes the primes were conceptually related to the targets they preceded. In order to check whether being aware of the primes might have influenced the priming effects, 2 ANOVAs were performed on R Hits and iK Hits after excluding participants who could read the words (N = 10; the remaining sample being N = 21). There were no significant priming effects on R Hits (F(2,40) = 1.36, p = .267, partial η^2 = .064) or on iK Hits (F(2,40) = .91, p = .409, partial η^2 = .044).

4.4.4. Short discussion

The results of Experiment 1 do not provide evidence for either model, given that there were no conceptual priming effects on participants' recollection of the target words. One explanation for the lack of conceptual priming effects overall can be connected to the test list context. Taylor and Henson (2012) found conceptual priming effects on recollection when they used repetition priming in the same experiment (in a blocked design, with separate repetition primes + unrelated primes blocks and conceptual primes + unrelated primes blocks); however, they failed to replicate the conceptual priming effect when all the blocks of the experiment used conceptual primes. In unpublished work, Taylor and colleagues replicated the conceptual priming effects on recollection when they included 2 initial blocks with no primes; this suggests that conceptual priming effects are sensitive to test list context. Thus, in the present experiment, we included 10 no-primed trials at the beginning of each test list in an attempt to enhance the priming effects. However, this might not have been sufficient and the lack of priming effect might, in fact, be due to the test list context.

Another methodological consideration for this experiment is represented by potential individual differences in language abilities. It might have been problematic that the different contexts of some targets involved the use of metaphors (e.g., abundance as context for OCEAN, vocal as context for

THUNDER, craving as context for ITCH, tolerate as context for SWALLOW). Not encoding the target words in the intended contexts or not having thought about the words in these contexts previously might have introduced noise in the results. In their review, Yee and Thompson-Schill (2016) highlighted that individual differences in cognitive abilities, as well as the extent to which individuals are sensitive to context, might have an effect on context-dependent conceptual representations. Rodd et al. (2016) showed in a series of experiments that participants' individual experience with different senses of words can impact their performance in experimental tasks involving semantic ambiguity. Having conceptual primes that were not straightforwardly related to the target word could account for the lack of conceptual priming effect to some extent. When designing the set of context and prime words for each target, some level of conceptual relatedness had to be sacrificed in order to have two different contexts for the same target. This motivates the use of homonyms in the next experiments, where we could have two distinct meanings, that do not overlap in terms of any semantic features.

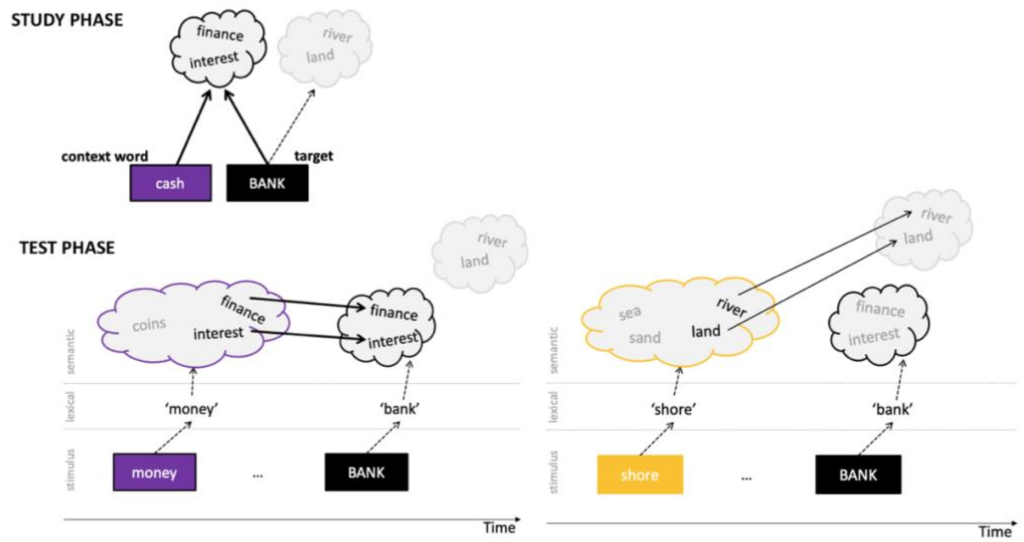


Figure 4.5. Visual representation of conceptual priming effects on recognition memory using homonyms as target stimuli. Top: 'cash' as context words shown at study will bias a meaning of the target word 'BANK'. Bottom left: the same meaning prime 'money' will reactivate the same meaning of the target BANK. Bottom right: the different meaning prime 'shore' will potentially activate the different meaning of the target and, based on our predictions, will not increase recollection since that meaning of the target 'BANK' is not the same as the encoded one.

4.5.1. Experiment 2

The aim of Experiment 2 was similar to that of Experiment 1, except that the target words were homonyms (i.e., words with two distinct meanings that do not share any semantic features). It has already been reported that showing a homonym in the recognition test phase with a word biasing the same meaning that was biased in the encoding increases recognition compared to showing a homonym with a word biasing the different meaning (Light & Carter-Sobell, 1970). This is referred to as *the context effect* and has been replicated also with using triads of words to bias the meaning of homonyms at study and test (Donaldson, 1981). In a similar way as we did in Experiment 1, in this experiment we biased the encoded meaning of target homonyms and used the same three types of priming conditions in the test phase. It is predicted that only primes related to the encoded meaning would increase recollection hits compared to the other primes (see Figure 4.5).

4.5.2. Methods

Participants. Thirty seven participants took part in Experiment 2. Based on our exclusion criteria described in the General Methods section, 5 participants were excluded from analysis (see Supplementary materials for a histogram of recollection false alarms). Finally, data from 32 participants (mean age = 19.78, SD = 2.66 years, 26 female) were included in the analyses.

Table 4.3.

Mean length and frequency of stimuli of interest used in Experiment 2

	Target words			Context words			Primes		
	Same meaning	Different meaning	Unrelated	Same meaning	Different meaning	Unrelated	Same meaning	Different meaning	Unrelated
Length	4.23 (0.82)	4.27 (1.05)	4.63 (0.89)	5.73 (1.91)	6.10 (1.73)	5.77 (1.65)	5.43 (1.38)	5.70 (1.34)	5.60 (1.28)
Frequency	27.35 (19.01)	41.07 (25.63)	36.32 (27.94)	28.54 (24.91)	32.81 (27.00)	28.47 (28.47)	17.46 (20.18)	20.60 (23.85)	32.36 (31.88)

Note. Standard deviations in parentheses.

Stimuli. The targets were 90 homonyms[3], each of them being assigned a context word and a prime. The prime was: (1) conceptually related to both the context

[3] We intended to use 120 homonyms which would have cycled through the following conditions: studied-same meaning priming, studied-different meaning priming, studied-unrelated priming, unstudied-related priming, unstudied-

word and the target homonym (e.g., context word: tree, target: BARK, prime: trunk), (2) conceptually related to the different meaning of the target homonym (e.g., context word: flavour, target: SEASON, prime: era), or (3) unrelated to the target homonym (e.g., context word: carnival, target: FAIR, prime: branch) (see full list in see Supplementary materials). All target homonyms, context words and primes were between 3 and 10 letters long and had written frequencies between 0.5 and 135 per million, based on CELEX (Medler & Binder, 2005) (see Table 4.3 for details). In addition to the stimuli of interest, we used 450 non-critical 'filler' words with similar word length and written frequencies as the stimuli of interest.

Procedure. The procedure followed the same structure as Experiment 1, with homonyms used as targets and context words and primes related to the two different meanings of the target rather than different contexts (see Figures 4.2 and 4.6). Prime awareness was checked in a similar way as in Experiment 1; we also asked whether "they noticed anything unusual about the words in the experiment", which was included to allow participants to volunteer their awareness of the use of homonyms in the experiment.

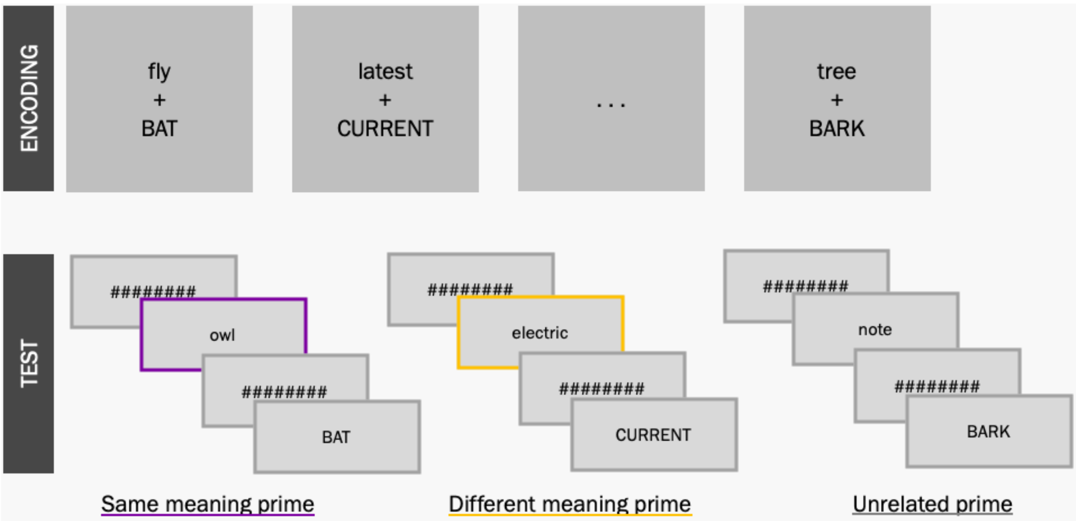


Figure 4.6. Priming conditions used in Experiment 2

4.5.3. Results

Mean proportions of R and iK responses for each condition are presented in Table 4.2 and Figure 4.4. Memory performance was above chance for both familiarity (p = .001) and recollection responses (p < .001) (see Table 4.1). There was a

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unrelated priming, across participants. However, because of a technical issue, the targets were not counterbalanced across conditions between participants and appeared in the same conditions for everyone. We therefore present the experiment here as non-counterbalanced by design.

significant main effect of priming on R Hits, as shown by the repeated-measures ANOVA on R Hits ($F(2,62) = 5.89$, $p = .005$, partial $\eta^2 = .160$). Planned contrasts showed that participants gave significantly more R responses to words preceded by same meaning primes compared to both words preceded by unrelated primes ($t(1,31) = 2.565$, $p = .015$) and words preceded by different meaning primes ($t(1,31) = 2.862$, $p = .007$). There was no significant difference between the proportion of R responses to words in the different meaning priming condition versus words in the unrelated priming condition ($t(1,31) = 1.159$, $p = .255$). The repeated-measures ANOVA with priming as factor on iK Hits did not yield a significant effect ($F(2,62) = 1.11$, $p = .337$, partial $\eta^2 = .034$).

In the encoding phase, on average, participants responded "related" for 65.88% of the trials of interest consisting of the target homonyms and their related context words (SD = 9.81, min = 44.44% and max = 80%). An additional set of analyses was performed on R and iK responses in the test phase after excluding the targets participants did not find related to their context words in the encoding phase (see Supplementary Materials). Although the pattern of means was similar, the ANOVA on R Hits did not show any significant priming effects ($F(2,62) = 2.19$, $p = .120$, partial $\eta^2 = .066$); and neither did the ANOVA on iK Hits ($F(2,62) = .84$, $p = .436$, partial $\eta^2 = .026$). It is noteworthy that this analysis was underpowered because approximately 1/3 of trials were excluded.

In terms of prime awareness, 26 participants were unaware, 2 participants were aware of something briefly flashed, 1 participant could read the words and 3 participants were aware that sometimes the primes were conceptually related with the targets they preceded. When analysing the data without the 4 participants who could read the words (remaining sample $N = 28$), the patterns of results were remained the same: a significant priming effect on R Hits ($F(2,54) = 4.62$, $p = .014$, partial $\eta^2 = .146$), but not on iK Hits ($F(2,54) = 1.74$, $p = .185$, partial $\eta^2 = .061$).

Homonym awareness. Seven participants noticed that some of the words used in the experiment had two different meanings. (21 participants were not aware that some stimuli were homonyms; 6 participants reported they were aware of some words having two meanings, but only after they were told about the homonyms; and 5 participants mentioned the use of homonyms themselves without being prompted).

4.5.4. Short discussion

The pattern of results was exactly as predicted by the encoded context reactivation account: recollection has been increased by conceptual primes related to the encoded meaning of the target words (same meaning primes) compared to both conceptual primes related to the different meaning (different meaning primes) and conceptually-unrelated primes. Both types of related primes (same meaning and different meaning) were conceptually related to the target words and they should have increased its conceptual fluency compared to the unrelated primes. However, recollection was increased only by same meaning primes, showing that the encoded meaning mattered in this case. In addition, familiarity was not affected by either type of the conceptual primes. Taken together, these results provide evidence for the encoding context reactivation account as opposed to the item conceptual fluency account which would have been supported by both same meaning and different meaning primes increasing recognition memory compared to unrelated primes. Because the target words did not rotate through conditions, it might be the case that the effects we observed were, at least in part, driven by uninteresting and unintended differences between stimuli in the various conditions. This potential limitation led to an improved design in Experiment 3.

4.6.1. Experiment 3

Experiment 2 showed the predicted pattern of results, with same meaning primes, but not different meaning primes, increasing recollection compared to unrelated primes. However, because stimuli did not rotate through the conditions between participants in Experiment 2, it is unknown to what extent the priming effects found were driven by the context priming manipulation and to what extent they were driven by differences between the stimuli in the various conditions. Therefore, one of the aims of Experiment 3 was to try to replicate the results of Experiment 2 with full counterbalancing. In addition, a few improvements were made. In Experiments 1 and 2 there was a rather high proportion of nominally related word pairs presented in the encoding phase that participants did not find related (~20% in Experiment 1 and ~35% in Experiment 2). Although participants' "unrelated" responses during encoding do not necessarily mean they were not successfully biased towards the intended context or meaning of the words, there is no objective way to assess which context or meaning they thought of. In order to control for this, in Experiment 3 we changed the encoding task by asking participants *how easy it is to find a semantic connection between the two words*. Also, rather than showing both word pairs that were related (i.e., our target words and their related context words) and word pairs that were not related (i.e., the fillers) as in Experiments 1 and 2, we only presented related word pairs (i.e., both target words and fillers). In this way, we intended to encourage participants to look for a semantic connection between the words.

Another improvement consisted of a newly designed set of stimuli that were validated by British English native speakers. A short piloting procedure was conducted to validate the set of homonyms as well as the context words and the primes to be used. First, a list of 172 homonyms was compiled using some of the stimuli from Experiment 2 (the words which had two separate entries in the English Oxford Dictionary (Oxford University Press, 2020)) and the list provided by Maciejewski and Klepousnitou (2016). In the first stage of the piloting procedure we aimed to investigate whether both meanings of the homonyms we selected can be easily generated. Four British English native speakers were asked to create short sentences to illustrate each of the two meanings of the homonyms without using a dictionary. Following this stage, 8 homonyms were removed from the list because no participant formulated sentences to distinguish between the two meanings correctly. The second stage of the validation procedure aimed to collect words that native speakers connect with each meaning of the homonyms. Thus, ten British English native speakers were asked to generate four words related to each meaning of the 164 homonyms, which were provided with short sentences (selected from stage 1) to illustrate each meaning. All the words generated were processed and after excluding words outside the length and written frequency range (3-9 letters, 1-150 per million, respectively), each meaning of the target homonym was associated with a list of generated words. These were listed for the rater in the final stage, in descending order of how many pilot participants (out of the 10) generated them. Finally, a British English native speaker (different from the pilot participants from Stages 1 and 2) chose the best words for each meaning: out of the 164 homonyms, 150 were selected on the basis that they were most likely to be known by British English native speakers. Importantly, the context words and the primes were chosen from the words generated by pilot participants at Stage 2.

4.6.2. Methods

Participants. Thirty eight participants took part in Experiment 3. Based on our exclusion criteria, data from 3 participants were removed from further analyses (see Supplementary materials). Finally, data from 35 participants (mean age = 19.20, SD = 1.35 years, 25 female) were included in the analyses.

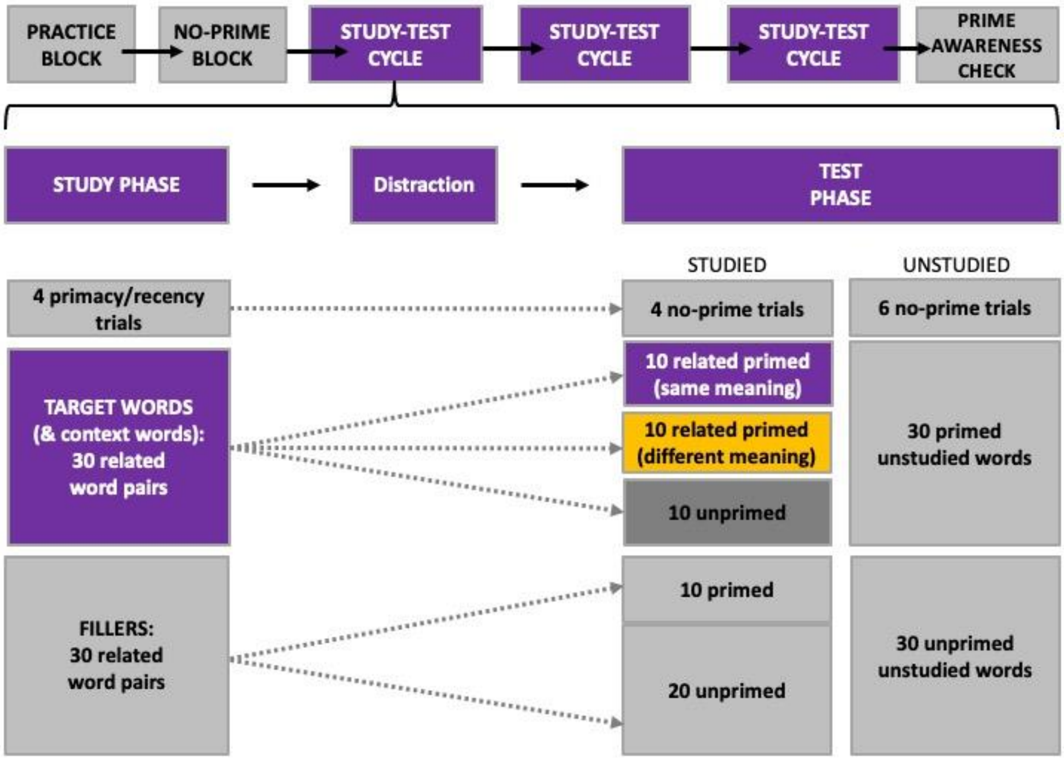

Figure 4.7. Experiment 3 design showing the overall structure of the experiment (top row) and what a study-test cycle consisted of (under the curly bracket). (The colours are symbolic, for display purposes only; during the experiment, the screen was grey. Also, the trial order was randomised in the experiment, for ease of interpretation the trials are shown sorted in the figure).

Stimuli. The target words were 150 homonyms, each matched with 2 related context word-prime pairs (see Supplementary materials). All target homonyms, context words and primes were between 3 and 9 letters long and had written frequencies between 1 and 150 per million based on CELEX (Medler & Binder, 2005) (target words: length M = 4.43 (SD = 1.04), frequency M = 24.59 (SD = 23.63); context words: length M = 6.15 (SD = 1.61), frequency M = 22.29 (SD = 28.22); primes: length M = 5.79 (SD = 1.54), frequency M = 24.24 (SD = 22.95)). In addition to the stimuli of interest, 'filler' words were used in the practice block, in the initial no-prime block, and in the blocks of interest, having similar word length and written frequencies as the stimuli of interest (see Figure 4.7). The 150 homonyms cycled through the following conditions: studied-same meaning priming, studied-different meaning priming, studied-unrelated priming, unstudied-related priming, unstudied-unrelated priming, across participants.

Procedure. The procedure[4] was similar to that of Experiment 2. The differences included: addition of an initial no-prime block which aimed to enhance the conceptual priming effect, modified encoding task (as described below, and the Context word + Target pair remained on the screen for 2.5s: 1s longer than in Experiments 1 and 2), and the use of an improved set of stimuli as described above. During encoding, instead of indicating whether the word pairs are related or not, participants were now requested to indicate how easy it is to find a semantic connection between the words. Consequently, only word pairs that were conceptually related were presented (both the homonyms – stimuli of interest – and the fillers) (see Figure 4.7). Through the change in the encoding task and increased display time of the context word and target, we aimed to encourage participants to find a semantic connection between the two words, to ensure we bias the encoded meaning of the target homonym.

4.6.3. Results

Memory performance was above chance for both familiarity and recollection responses ($p < .001$ for both comparisons) (see Table 4.1). Mean proportions of R and iK responses for each condition are presented in Table 4.2 and Figure 4.4.

The repeated-measures ANOVA on R Hits did not show a significant effect of priming ($F(2,68) = 1.40$, $p = .254$, partial $\eta^2 = .040$). Planned contrasts were performed to compare the proportions of R Hits between the priming conditions. There were no significant differences between the same meaning and unrelated priming conditions ($p = .440$, uncorrected, one-tailed) or between different meaning and unrelated priming conditions ($p = .105$, uncorrected, one-tailed), but there was a non-significant trend difference between same meaning and different meaning priming conditions ($p = .063$, uncorrected, one-tailed) with a higher proportion of R hits in the same meaning priming condition.

The repeated-measures ANOVA with priming as factor on iK Hits did not show a significant effect of priming ($F(2,68) = 2.67$, $p = .076$, partial $\eta^2 = .073$).

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[4] Although it was intended to record them, due to a technical error in the experiment, prime and homonym awareness were not recorded.

Table 4.4.

Mean proportions of responses separately for dominant encoding meaning and subordinate encoding meaning in Experiment 3

	Studied words (homonyms only)					
	Dominant encoding meaning			Subordinate encoding meaning		
	Same meaning prime (dominant)	Different meaning prime (subordinate)	Unrelated prime	Same meaning prime (subordinate)	Different meaning prime (dominant)	Unrelated prime
R	0.35 (0.23)	0.31 (0.19)	0.34 (0.22)	0.31 (0.19)	0.29 (0.21)	0.31 (0.23)
iK	0.36 (0.23)	0.38 (0.23)	0.37 (0.24)	0.33 (0.21)	0.39 (0.22)	0.35 (0.21)
New	0.43 (0.18)	0.43 (0.21)	0.42 (0.22)	0.46 (0.19)	0.44 (0.20)	0.44 (0.22)

Note. Standard deviations in parentheses.

A separate set of repeated-measures ANOVAs was performed including encoded meaning dominance as factor in addition to priming (see Table 4.4), although the dominant/subordinate encoding context was coded post-hoc. One of the two meanings of a homonym is used more often, being called dominant (e.g., BANK-cash), and the other is encountered less often, being called subordinate (e.g., BANK-river). The dominance of the meaning we tried to bias participants to encode during the study phase was coded post-hoc for each target homonym, for each participant. The first entry of the word in the English Oxford Dictionary (Oxford University Press, 2020) was considered to be the dominant meaning and the next entry the subordinate meaning of the word[5]. The inclusion of Encoded meaning dominance as factor with 2 levels: Dominant and Subordinate aimed to investigate whether the priming effects we expected were modulated by the meaning dominance.

The repeated-measures ANOVA with priming and encoded meaning dominance as factors on R responses did not show any significant main effects of encoded meaning dominance ($F(1,34) = 2.91$, $p = .097$, partial $\eta^2 = .079$), of priming ($F(1,34) = 1.12$, $p = .331$, partial $\eta^2 = 032$) and no significant interaction between the two factors ($F(2,66) = .35$, $p = .709$, partial $\eta^2 = .010$). The analysis on iK responses when including encoded meaning dominance as factor yielded no significant main effects of priming ($F(2,68) = 1.36$, $p = .263$, partial

[5] The dominant and subordinate meanings were also coded based on previous homonym databases that looked at meaning frequency. For less than 10% of the homonyms used in the experiment, the databases consulted (i.e., Maciejewski & Klepousniotou, 2016; Nelson et al., 1980; Twilley et al., 1994) pointed to the other meaning as being the dominant one, as opposed to the entry order in the Oxford Dictionary. The analyses that included encoding meaning dominance as a factor were performed again with recoded meanings and the patterns of results are the same as the ones reported in-text (see Supplementary Materials).

η^2 = .038), of encoded meaning dominance (F(1,34) = .26, *p* = .617, partial η^2 = .007), nor a significant interaction between the two factors (F(2,66) = .35, *p* = .708, partial η^2 = .010).

In this experiment, we used a new graded judgment encoding task where the proportions of encoding trials participants found related was higher than in the previous binary judgment task (M = 93.95%, SD = 9.86, min = 50% and max = 100%). However, for completeness, an additional set of analyses was performed on R and iK responses after excluding the target words participants did not find related to their context words (i.e., where participants answered '0') in the encoding phase. We found a similar pattern of results as reported above: the ANOVA on R Hits did not yield a significant main effect of priming (F(2,68) = 1.66, *p* = .197, partial η^2 = .047); however, the ANOVA on iK responses showed a main effect of priming (F(2,68) = 3.51, *p* = .035, partial η^2 = .094), with post-hoc tests revealing a significantly higher proportion of iK responses to words preceded by different meaning primes compared to word preceded by same meaning primes (t(1,34) = 3.136, *p* = .004, Bonferroni-corrected significance level = .017).

4.6.4 Short discussion

Although there was no significant priming effect on recollection, there was a non-significant trend for an increase of 'remember' responses in the same meaning priming condition compared to the different meaning condition; noteworthy, in the same direction as in Experiment 2. This provides support (albeit relatively weak evidence) for the encoding context reactivation account. Results on iK responses show an increase in familiarity for words preceded by different meaning primes compared to same meaning primes, a pattern that appeared more clearly when removing the targets participants did not find related to their context words during the study phase. This priming effect on familiarity was surprising and it seems to suggest that when conceptual primes are not related to the encoded context, they influence recognition memory judgments through a different mechanism. Both types of conceptually related primes are presumably increasing conceptual fluency of the target words they precede; when they are, in addition, related to the encoded meaning of the target, they seem to increase recollection and when they are related to a different meaning they seem to increase familiarity. However, the results are less clear than the ones in Experiment 2, mainly because there were no differences between any of the related priming conditions and the unrelated priming condition. In order to investigate the effects on recognition memory of same meaning and different meaning primes compared to unrelated primes, we separated them between-groups in the next experiment.

4.7.1. Experiment 4

Experiment 2 and 3 showed interesting differences between same meaning and different meaning priming conditions, but the differences between (same/different) related and unrelated priming conditions were less consistent. Words preceded by same meaning primes received more 'remember' responses than words preceded by different meaning primes, an effect which was only significant in Experiment 2, whereas the opposite was true for 'familiar' responses in Experiment 3. In Experiment 4, we separated the related priming conditions in a between-groups design: in one group we used same meaning primes and unrelated primes only, and in the other group we used different meaning primes and unrelated primes, in order to compare directly the priming effects of each type of conceptually related prime. By separating the two types of related primes between groups, we aimed to clarify whether the differences observed between the related priming conditions on the proportion of R responses, in particular, correspond to a facilitatory effect (in which case we would expect a difference between same meaning priming > unrelated priming) or to an inhibitory effect (different meaning priming < unrelated priming). We predicted conceptual priming effects on recollection in the Same meaning group only, in line with the encoding context reactivation account. Based on the results of Experiment 3, we predicted that if conceptual primes affect familiarity, the priming effects will be observed in the Different meaning group only.

4.7.2. Methods

Participants. Seventy-two participants took part in Experiment 4, randomly allocated to one of the two groups: Same meaning group or Different meaning group. Exclusion of 3 participants from further analyses was based on the distribution of recollection false alarms rather than the IQR-based method used in the previous three experiments. The reason for this was the very low rate of recollection false alarms overall (see Supplementary materials). Finally, there were 69 participants included in the analysis: 34 in the Same meaning group (mean age = 19.15, SD = 1.26 years, 33 female) and 35 in the Different meaning group (mean age = 19.34, SD = 1.03 years, 29 female).

Table 4.5.

Mean length and frequency of stimuli of interest used in Experiment 4

	Target words	Meaning 1 (Dominant)		Meaning 2 (Subordinate)	
		Context words	Primes	Context words	Primes
Length	4.47 (1.04)	6.20 (1.54)	5.83 (1.55)	6.13 (1.69)	5.72 (1.55)
Frequency	24.56 (23.70)	22.57 (26.47)	25.31 (22.36)	21.16 (29.00)	22.60 (23.10)

Note. Standard deviations in parentheses.

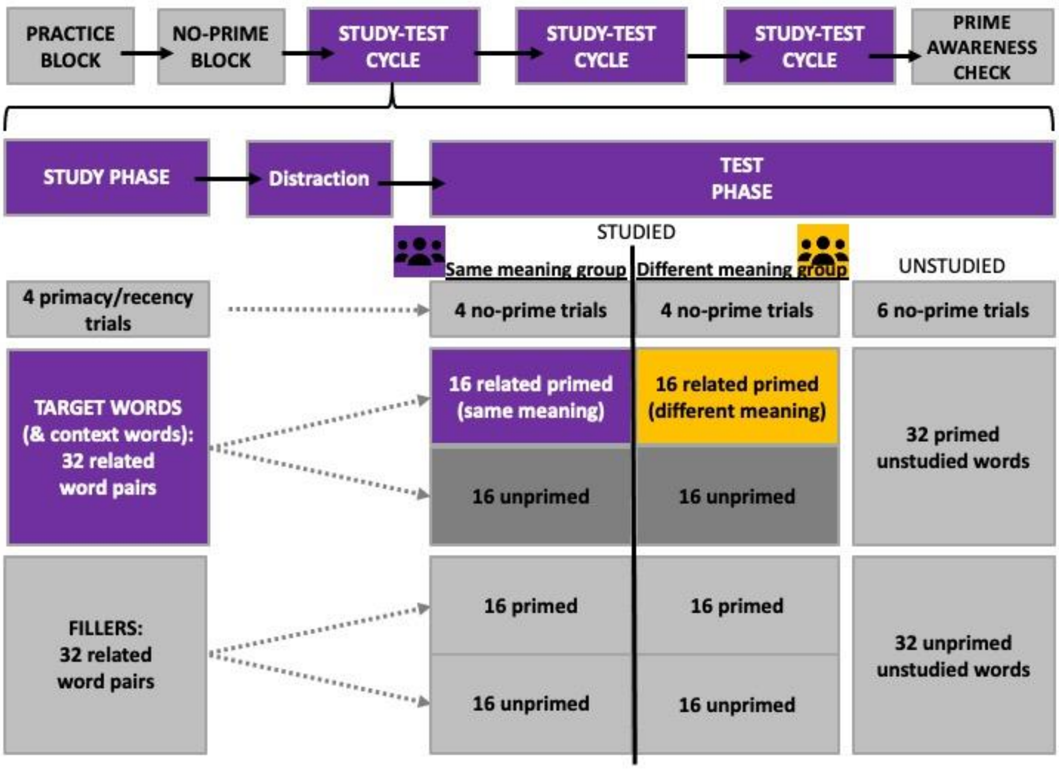

Figure 4.8. Experiment 4 design showing the overall structure of the experiment (top row) and what a study-test cycle consisted of (under the curly bracket). The colours are symbolic, for display purposes only; during the experiment, the screen was grey. Also, the trial order was randomised in the experiment, for ease of interpretation the trials are shown sorted in the figure. Also, the priming conditions differed between-groups for studied words, as shown in the figure.

Stimuli. The same stimuli as in Experiment 3 were used with homonyms cycling through the following conditions: encoded meaning dominance (dominant/subordinate) x prime type at test (related/unrelated) + unstudied (prime type: dominant, subordinate, unrelated). The stimuli of interest were arranged in lists differently compared to Experiment 3, so we can control for the encoding dominance meaning (i.e., to have an equal number of homonyms for which we biased the dominant meaning and for which we biased the subordinate meaning in the encoding). In the Same meaning group, the conceptual primes were always related to the encoded meaning (e.g., if the encoded meaning was dominant, the prime was also related to the dominant meaning); whereas in the Different meaning group, the conceptual primes were always related to the other meaning than the encoded one (e.g., if the encoded meaning was dominant, the prime was related to the subordinate meaning) (see Table 4.5 and Figure 4.8).

Procedure. The procedure was identical to the one employed in Experiment 3, except that (1) only same (or different) meaning and unrelated primes were used in a between-group design and (2) dominance of the encoded meaning was counterbalanced.

Statistical analyses. We performed an additional 2 (group: Same meaning/Different meaning) x 2 (priming: related/unrelated) x 2 (encoded meaning dominance: dominant/subordinate) ANOVAs on R and iK responses.

4.7.3. Results

Mean proportions of R and iK responses for each condition are presented in Table 4.2 and Figure 4.4. Memory performance was above chance for both familiarity and recollection responses for both groups (p <.001 for both comparisons) (see Table 4.1).

The mixed ANOVA with Group as between-subjects factor and priming as within-subjects factor on R responses did not show any significant main effects of priming ($F(1,67) = .27$, $p = .608$, partial $\eta^2 = .004$), of group ($F(1,67) = 3.41$, $p = .069$, partial $\eta^2 = .048$) and no significant interaction between the two factors ($F(1,67) = .002$, $p = .965$, partial $\eta^2 < .001$). The ANOVA on iK responses did not show any significant main effects of priming ($F(1,67) = 1.66$, $p = .202$, partial $\eta^2 = .024$), of group ($F(1,67) = .26$, $p = .610$, partial $\eta^2 = .004$) or a significant interaction of the two factors ($F(1,67) = 1.39$, $p = .242$, partial $\eta^2 = .020$).

Table 4.6.

Mean proportions of responses separately for dominant encoding meaning and subordinate encoding meaning in Experiment 4

Response	Studied words (homonyms only)							
	Same meaning group				Different meaning group			
	Dominant encoding meaning		Subordinate encoding meaning		Dominant encoding meaning		Subordinate encoding meaning	
	Primed (dominant)	Unprimed	Primed (subordinate)	Unprimed	Primed (subordinate)	Unprimed	Primed (dominant)	Unprimed
R	0.35 (0.18)	0.34 (0.18)	0.33 (0.17)	0.34 (0.18)	0.44 (0.18)	0.43 (0.17)	0.37 (0.18)	0.39 (0.19)
iK	0.45 (0.19)	0.43 (0.21)	0.53 (0.17)	0.47 (0.18)	0.42 (0.23)	0.47 (0.21)	0.48 (0.17)	0.43 (0.21)
New	0.37 (0.20)	0.37 (0.17)	0.32 (0.15)	0.36 (0.18)	0.33 (0.16)	0.30 (0.14)	0.33 (0.15)	0.35 (0.15)

Note. Standard deviations shown in parentheses.

After including Encoding meaning dominance as a factor, we performed 2x2x2 (group by priming by encoding meaning dominance) ANOVAs on R and iK responses separately (see Table 4.6). The ANOVA on R responses showed a significant main effect of encoding meaning dominance ($F(1,67) = 6.30$, p = .015, partial η^2 = .086) with a higher proportion of R responses for words presented in a dominant encoding context versus words presented in subordinate encoding contexts. The rest of the main effects and interactions were not significant (*p*s > .05; reported in Supplementary Materials).
The 2x2x2 (group x priming x encoding meaning dominance) ANOVA on iK responses yielded a significant interaction between Encoding meaning dominance * Priming ($F(1,67) = 5.02$, p = .028, partial η^2 = .070), post-hoc tests showing a significant priming effect on iK responses (i.e., related > unrelated) to target words presented in subordinate encoding contexts ($t(1,68)$ = 3.116, p = .003), but not on iK responses to target words presented in dominant encoding contexts (t(1,68) = -.591, p = .557).

On average, participants responded “related” (1/2/3) for 93.19% of the encoding trials (SD = 9.03, min = 61.46% and max = 100%). For completeness, the initial analyses were repeated after excluding the encoding trials participants did not find related or missed responding. The patterns of results are the same as the ones obtained when including the whole dataset (see full details in Supplementary Materials).

In terms of homonyms awareness, 8 and 10 participants in in Same and Different meaning groups, respectively, were not aware of the use of homonyms even after being told about them; 18 and 21 participants did not mention the use of homonyms themselves but reported being aware of their use during the experiment after having been told we used ambiguous words; 8 and 4 participants mentioned the use of homonyms themselves. In terms of prime awareness, 22 and 17 participants in the Same and Different meaning groups, respectively, were not aware of the primes; 8 and 13 participants were aware of something being briefly flashed but could not read the words; 1 and 3 participants could read the some of the primes; 3 participants and 2 participants noticed also that some of the primes were conceptually related to the target words they preceded. Analyses on a subsample of participants who could not read the primes (Same meaning group: N = 30; Different meaning group: N = 30) showed similar patterns of results to the ones when looking at the whole dataset were obtained when excluding participants who reported reading some of the primes.

4.7.4. Short discussion

There were no priming effects on recognition memory judgments in any of the two groups, this replicating in a way the results of Experiment 3. We did not find significant differences between the related priming conditions (same meaning or different meaning) and the unrelated priming condition in the previous experiment. When separating the related priming conditions between-groups and comparing them with the unrelated priming condition, no effects were observed. Adding the encoding meaning dominance as a factor showed no significant differences on the proportion of 'remember' responses. However, analyses on iK Hits showed that familiarity was increased in both groups when homonyms were encoded with their subordinate meaning. Although there were no priming effects on recollection, there was an effect of encoding meaning dominance on R responses, with a higher proportion of 'remembered' homonyms that were presented in a dominant context at study compared to homonyms presented in a subordinate context at study. This finding is consistent with the notion that the semantic overlap between study and test is important for recollection. In this case it was not due to priming, but rather driven by an intrinsic feature: the dominance of the meaning. If the dominant meaning is most likely to come to mind at test, and that meaning formed the context at encoding, then overlap is likely. It appears, therefore, that the encoded meaning dominance played an important role, possibly overriding the priming manipulations because the dominance of the meaning was enough to ensure it activates at test.

4.8. General Discussion

The aim of the study was to investigate the mechanism by which masked conceptual priming influences recognition memory and, in particular, recollection. This was done by manipulating the encoded context (in Experiment 1) or meaning (in Experiments 2-4) of the target words and using conceptual primes either related to the same context/meaning or related to a different context/meaning. In Experiments 3 and 4, we also looked at how encoding meaning dominance of homonyms modulated the priming effects, given that dominance relates to the likelihood that a particular meaning will come to mind. The encoding context reactivation account predicts that relatedness to the encoding context should lead to more recollection hits than if the prime is not related to the encoding context. The key prediction is that same vs different to encoding matters. This was partially confirmed by the pattern results in Experiments 2 and 3 where we used homonyms as targets and prime type (same meaning/different meaning vs encoding) was manipulated within participants. Same meaning primes increased the proportion of R responses compared to unrelated primes (in Experiment 2) and compared to different meaning primes (in Experiments 2 and 3). This partially confirms the proposed encoding context reactivation account (Taylor and colleagues). However, this effect was not present when prime type (same/different meaning vs encoding) was manipulated between participants (Experiment 4), nor when stimuli were non-homonyms and contextual meanings were less distinct (Experiment 1). Additionally, in Experiment 4, we found an effect of encoding meaning dominance on recollection, with more words being 'remembered' if they were presented in a dominant encoding rather than a subordinate encoding context.

Conceptual priming effects on familiarity, although not the focus of this paper, tell an interesting story. In Experiment 3, where prime type (same/different meaning vs encoding) was manipulated within participants, different meaning primes increased familiarity compared to same meaning primes, particularly when words were encoded with their subordinate meaning (but there were no differences compared to unrelated primes). In Experiment 4, where prime type was manipulated between participants, both same meaning and different meaning primes increased familiarity compared to unrelated primes, but only when words were encoded with their subordinate meaning.

In Experiment 4 (and also in Experiment 3, although not reaching statistical significance), both dominant and subordinate primes increased familiarity compared to unrelated primes, only when the subordinate meaning of homonyms was encoded. In the same experiment, participants remembered (> R hits) more homonyms encoded with their dominant meaning compared to those encoded with their subordinate meaning, whereas encoded meaning dominance did not have an effect on the proportions of familiarity responses. It can also be read as: being encoded with its subordinate meaning a homonym is less likely to be recollected. This presumably leaves more room to move the conceptual fluency of these words and might render memory judgments for homonyms encoded with their subordinate meanings more sensitive to fluency manipulation since participants are likely to rely more on fluency cues when there is no recollection of a word (Kelley & Rhodes, 2002). In addition, when pairing a homonym with a context word biasing its subordinate meaning, both its meanings might have been activated at certain levels (e.g., Booth, Harasaki & Burman, 2006; Warren et al., 1978); however, findings have still not converged in regards with what happens with the non-selected meaning (i.e., in our case, the meaning that was not biased during encoding): whether it is suppressed (MacDonald et al., 1994) or whether it is activated up to a certain threshold and retained for eventual reactivation in case the selected meaning is not correct (McRae, Spivey-Knowlton & Tanenhaus, 1998).

It also seems that the mechanism of attributing item conceptual fluency to familiarity is modulated by prime types included in the same test list: when there were same meaning, different meaning and unrelated primes within a list (Experiment 2 and 3), different meaning primes > same meaning primes; when there were same meaning and unrelated only, same meaning > unrelated; when there were different meaning and unrelated only, different meaning > unrelated. The effect of conceptual primes on recollection is modulated by prime types included within the same test list, but in a different way. In Experiments 2 and 3, when there were same meaning, different meaning and unrelated primes, same meaning > different meaning. In Experiment 4, when there were same meaning and unrelated primes or different meaning and unrelated primes in the same test list, there were no priming effects. It has been reported before that, while conceptual primes increased recollection compared to unrelated primes when the experiment included blocks with repetition primes as well, this priming effect on recollection disappeared when there were only conceptual primes within the experiment (Taylor & Henson, 2012). It can be the case that sufficient between-trial variability is necessary before participants start to rely on the 'semantic network activation' channel.

Limitations. The results of the present study might not be directly comparable with previous experiments investigating the effects of conceptual priming on recognition memory mainly because of the change in the encoding task. While previous experiments (Taylor and colleagues, 2012; 2013, Li et al., 2017) involved making interestingness judgments during encoding, the four experiments reported in this chapter had participants making relatedness judgments about pairs of words during encoding. The intention of the encoding task was to bias the context participants encoded the target words in; however, presenting the target words with another context word consequently offered participants an additional cue to potentially base their recollection judgments on. Although they have been instructed that they should choose the 'remember' option if they brought back to mind *any* additional detail related to the presentation of the target word during encoding (and not only when they manage to bring back to mind the other word), it can be argued that the likelihood to choose 'remember' when participants did not recall the paired word decreased. This is a limitation of the design which we acknowledge, and which could have influenced the pattern of results. More specifically, in Experiment 4, 'related same' primes increased familiarity and not recollection. We cannot exclude the possibility that a proportion of the familiarity responses was actually "non-criterion" recollection (i.e., participants remembered the word but not the context word presented during the encoding phase and they chose 'familiar' as a consequence).

Chapter 5: General Discussion

"It is ordinarily very practical to believe that one is in direct contact with a "real" present and a "real" past. However, the possibility of illusions of perception and memory indicate that one should not become too comfortable in that belief. Appearances of familiarity can be deceptive." (Whittlesea et al., 1990, p. 731).

In order to save energy, time and mental resources, we learn how to automatise our interactions with the environment. As first described by Tversky and Kahneman (1974), a result of this process is that many daily decisions we make are based on automated processes resulted from learned experiences. These cues we rely on to find shortcuts in making complex decisions, that would otherwise take a long time, are called heuristics. They are very useful most of the time, but they are also the foundation of our biases which can lead to systematic errors. How people make memory decisions, and how the way in which stimuli are experienced at the time of the memory decision influences these memory decisions, have been of great interest in the study of memory. In this exploration, the effects on recognition memory of processing fluency, or the speed or ease of processing a present stimulus, are well-documented. However, the specific process by which non-mnemonic fluency is attributed to memory, and especially its neural mechanism, are not well understood. One aim of this thesis was to elucidate how participants' bias of attributing non-mnemonic fluency to prior exposure could be switched off or reduced and how this switching on/off is driven by changes in the neural system involved in a recognition memory task. Another aim of the thesis was to examine the mechanism by which conceptual priming influences recognition memory. While short-term repetition priming of test stimuli increases familiarity of both studied and unstudied test items, non-associative conceptual priming effects have been found on recollection. We proposed that the latter can be explained through an encoding context reactivation account rather than through a fluency attribution account.

We will briefly list the main findings of the thesis and then we will explore each of them more in-depth. Chapters 2 and 3 focused on the non-mnemonic fluency attribution to memory mechanism, and Chapter 4 investigated the encoding context reactivation account of conceptual priming effects on memory.

Behavioural results of Chapters 2 and 3 showed that study-test modality mismatch discouraged participants to rely on fluency cues in their memory judgments. We found repetition priming effects on “old” and “familiar” responses only when the modality of the study and test phases was the same (at least partially). In terms of ERPs sensitive to priming and memory, both the study-test modality match and the study-test modality mismatch groups showed similar priming effects (more positive going ERPs for primed versus unprimed trials in the 50-250ms and 300-500ms time windows) and memory effects (old/new FN400 and LPC). Using DCM on evoked responses we found decreased connectivity strength between the right perirhinal cortex and the right dorsolateral prefrontal cortex in the study-test modality match group. These results will be interpreted below in the non-mnemonic fluency attribution to memory framework. The other branch of the thesis investigated conceptual priming effects on recollection. Chapter 4 involved a series of four experiments where we found some level of support for the encoding context reactivation account. Although quite subtle, when we found conceptual priming effects on recollection (in Experiments 2), they were due to primes related to the encoded context. In turn, when conceptual priming increased familiarity (in Experiments 3 and 4), these effects were either through primes related to a different context than the encoded one versus same context primes or through both same context and different context primes versus unrelated primes, supporting the item fluency account.

5.1. Repetition priming effects on recognition memory

It is important to distinguish between two types of fluency: mnemonic and non-mnemonic. The former is due to faster processing of a current stimulus due to its prior encounter, while the latter can stem from a variety of other sources, for example clarity or short-term priming. The experiment reported in Chapter 2 of the thesis investigated fluency attribution to memory by manipulating the study-test modality match and the context of the study list, in a between-groups design: one group received visual study lists, a second group received auditory study lists, the third group studied half of the words visually and half of the words auditorily; all three groups received visual memory test lists. It has been found previously that a mismatch between study and test can reduce the repetition priming effects on “old” responses, and also that having studied both visual and auditory words will render participants prone to the repetition priming effects for all trials, regardless of the study modality, as long as the study list was mixed (Westerman et al., 2002). We replicated these results on the proportion of “old” responses. In addition, we found that all 3 groups showed priming effects on response times associated with both familiarity and recollection, as estimated through the R/K paradigm; this suggests they all experience a similar level of increased speed of processing for primed versus unprimed trials. However, similar to previous studies, we found that only participants in the visual and the auditory/visual groups showed increased proportions of familiarity responses for primed versus unprimed words. Participants who studied all the words auditorily, although they showed priming effects in response times, they did not show an increase in the proportion of familiarity responses. We successfully managed to reduce their bias to attribute non-mnemonic fluency to memory by changing the study modality compared to test. The fact that participants in the auditory/visual group showed priming effects suggests that it is not only study-test modality match that matters, but also the study list context overall. By studying half of the words in the same modality as they received the memory test, the fluency attributional “system” was switched on and they (unconsciously) considered *visual* fluency relevant for their familiarity-based memory decisions. Importantly, we replicated previous findings using study-test cycles rather than one single study-test list. This allows the investigation of the fluency attribution to memory process using this paradigm with neuroimaging techniques, since it offers a higher number of trials while maintaining the possibility to switch on/off the attributional system. In addition, we consider the use of this paradigm as ideal for looking into the switching on/off non-mnemonic fluency attribution to memory, since the memory test participants received is identical in terms of instructions, modality, prime (un)awareness, prime duration, and prime-target SOA; such parameters have been found by previous research to modulate priming effects. However, they would not allow for direct comparison between groups without potential confounding factors stemming from these differences in the test list.

The experiment reported in Chapter 3 of the thesis had a similar design as the previous experiment, but only 2 groups were included (visual study group and auditory study group), while participants’ brain responses were recorded using EEG. Behavioural results replicated previous findings (Miller et al., 2008; Westerman et al., 2002; Chapter 2 of this thesis), with participants in the study-test modality match group experiencing priming effects, but not participants in the study-test modality mismatch group. Participants who studied the words visually, but not participants who studied the words auditorily, showed increased proportions of “old” responses for primed versus unprimed words, regardless of study status. In addition, only participants in the visual study group showed priming effects on familiarity, for unstudied words only, suggesting that study-test modality match switches on the non-mnemonic fluency attribution to memory. When looking at familiarity calculated under independence assumptions participants in the visual study group show priming effects on both studied and unstudied words; whereas participants in the auditory study group showed priming effects on familiarity for studied words only. Noteworthy, these priming effects on studied words were stronger in the visual study group than in the auditory study group. In addition, the fact that the priming effect on false alarms only occurred in the visual study group suggests that the non-mnemonic fluency attribution to memory system was switched on only in the study-test modality group. In this experiment, we did not find priming effects on response times, but a potential reason for this can be that participants had to wait for each word to disappear from the screen (for 1s) before making a memory decision. Nonetheless, priming effects on response times is only an indirect way to measure processing fluency, since participants make memory decisions to the words rather than mere perceptual responses. Our replication of previous results shows that changing the study modality to match or not the test modality can modulate participants' reliance on non-mnemonic fluency for their memory decisions.

These consistent results of the two experiments provide an ideal paradigm to investigate the switching on/off of fluency attribution to memory while keeping the parameters of the memory test list constant across groups. When participants study the words in the auditory condition and then their memory is tested visually, they do not find the non-mnemonic *visual* fluency of test words (induced through priming) relevant for their memory decisions. Arguably, they experience the same level of mere processing fluency as participants who studied the words visually, as shown by similar priming effects on response times (in the first experiment), but they do not attribute this to prior exposure. Priming effects experienced by participants who studied both visual and auditory words suggest that it is not study-test modality match per se that renders them prone to experience priming effects, but the study context is important to unconsciously create the expectations around the cues that might be useful for memory decisions.

5.2. Neural mechanism underlying fluency attribution to memory

In Chapter 3, we also investigated group differences in terms of ERP components sensitive to priming and memory. We replicated previously reported old/new effects in the FN400 (300-500ms following target onset) and LPC (500-800ms) time windows (Rugg & Curran, 2007). In both groups, ERPs associated with K hits and R hits were more positive going than ERPs associated with CRs in the 300-500ms time window at frontal electrodes; and ERPs associated with R hits were more positive going than ERPs associated with K hits in the 500-800ms time window at parietal electrodes. We found a priming effect in the 300-500ms time window at frontal electrodes, with ERPs associated with priming trials being more positive going than ERPs associated with unprimed trials. This could also reflect conceptual priming processes underlying familiarity (Voss & Federmeier, 2011) since it has a similar topography to the FN400 old/new effect. We replicated Woollams et al. (2008) results showing ERP priming effects in the P2 time window (150-250ms); our data showing a broader P2 time window: 50-250ms. Overall, our canonical ERP results are in line with previous research.

Importantly, there were no group differences and no group by priming interactions in terms of ERP mean time-window amplitudes, suggesting the behavioural differences in fluency attribution to memory are not reflected in amplitude differences of these ERP components. This lack of group differences motivated our DCM analysis where we investigate connectivity strength between brain regions likely to be involved in the neural system underlying fluency attribution to memory. From the models we compared (all including the same regions of interest, but differing in terms of the forward/forward and backward connections), the winning DCM model across groups consisted of bilateral visual areas connected through both forward and backward connections to bilateral PRC, and the right PRC connected through both forward and backward connections to the right DLPFC; additionally, the model had lateral connections between PRC cortices, which were not of interest for our group differences. We estimated this model in each individual and compared the connectivity strength of each of the six connections of interest (between bilateral visual areas and bilateral PRC and between right PRC and right DLPFC) between groups. Interestingly, we found stronger connectivity in the auditory group for the forward connection between right PRC and right DLPFC. Perirhinal cortex activity decrease has been associated with increased oldness in fMRI studies (e.g., Gonsalves et al., 2005), more recently PRC activity increase positively correlating with novelty strength (Kafkas & Montaldi, 2014). Dew and Cabeza (2013) showed that PRC is involved in fluency tracking, with decreased PRC activity being associated with fluently perceived stimuli, regardless of whether the fluency is due to prior exposure or not. The right DLPFC has been associated with retrieval monitoring and mainly to be involved in familiarity-based memory decisions (Fletcher & Henson, 2001).

5.3. Conceptual priming effects on recognition memory

The overarching aim of the thesis was to investigate short-term masked priming effects on recognition memory, more specifically how repetition priming and non-associative conceptual priming effects support an item fluency account or an encoding context reactivation account. The item fluency account is consistently supported by repetition priming effects on recognition memory, where by preceding test stimuli with their own brief masked presentation increases their processing fluency, which in turn, is attributed to prior exposure whether the stimulus was studied or not. However, we proposed that the item fluency account cannot explain non-associative conceptual priming effects on recollection. Results reported in Chapter 4 found some supporting evidence for the encoding context reactivation account when looking at conceptual priming effects on recollection, and, although not predicted, some level of support for the item fluency account when looking at conceptual priming effects on familiarity.

In a series of four experiments, we aimed to control for the encoded context that we could then “reactivate” through masked conceptual priming in order to investigate how the encoding context reactivation account might explain conceptual priming effects on recognition memory. Because we were mainly interested in conceptual priming effects on recollection and whether they rely on the encoded context or not, only studied items were of interest; also, participants do not make too many recollection false alarms when the R/K paradigm is employed (Tulving, 1985), thus, we did not analyse false alarms in any of the experiments in Chapter 4. In all four experiments we biased the context in which participants encoded a set of target words and then used three types of primes: related to the target word and to the same encoded context (i.e., same context primes), related to the target word, but to a different context than the encoded one (i.e., different context primes), and unrelated to the target word (i.e., unrelated primes). Experiments 2, 3, and 4 used homonyms as target stimuli, while Experiment 1 used words with a single meaning. For Experiments 2-4, we biased the encoded meaning, rather than context.

If our proposed encoding context reactivation account was true, we predicted that the encoded context would matter for conceptual priming effects on recognition memory and we would observe an increase in recollection-based responses for target words preceded by same context/meaning primes compared to the other priming conditions. In turn, if the item fluency account was true, we would observe an effect of both same context and different context primes compared to the unrelated primes on recognition memory responses, since both types of related primes would increase conceptual fluency of target words they precede.

In Experiment 1, we did not find any effects of priming on either familiarity or recollection and in Experiment 4 we did not find conceptual priming effects on recollection. In Experiment 2, we found the exact predicted pattern of results on recollection, with same meaning primes increasing the proportion of recollection responses compared to both different meaning primes and unrelated primes. In this experiment, there were no effects on familiarity responses of either type of primes. In Experiment 3, we found an increase in the proportion of recollection responses to targets preceded by same meaning primes when compared to targets preceded by different meaning primes, although this was only a non-significant trend. Results of these two experiments provide support for the encoding context reactivation account, given that recollection was increased only when conceptual primes were related to the encoded meaning. At the same time, these results offer evidence against the item fluency account as a valid explanation for the conceptual priming effects on recollection. Both same meaning and different meaning primes presumably increase conceptual fluency of the target word they precede. If solely item conceptual fluency matters for conceptual priming effects on recollection, then we would have observed increased proportions of recollection responses for both type of related primes.

Results on familiarity, although not predicted, tell an interesting story. In Experiment 4, both same meaning and different meaning primes increased familiarity compared to unrelated primes, but only when words were encoded in subordinate contexts. Results in Experiment 4 directly align with the conceptual item fluency account, considering that both same meaning and different meaning primes increased *the feeling of having seen* the target words (i.e., familiarity) compared to unrelated primes. While this does not provide support for our proposed encoding context reactivation account, it does not bring contradictory evidence either, since the effects are observed on familiarity and not on recollection. It extends previous research (e.g., Rajaram & Geraci, 2000), showing that non-associative conceptual primes can increase item conceptual fluency which can be attributed to familiarity. Indeed, using lexical decision tasks, research reports priming effects of non-associative conceptual primes (e.g., Ferrand & New, 2003), suggesting that non-associative 'pure' conceptual primes also increase target processing fluency. Interestingly, in our study, this happened when the subordinate meaning of the homonyms was encoded, and not when the dominant meaning was encoded. Leaving our priming manipulation aside, it can be the case that when homonyms were encoded in a subordinate context and then, during test, the dominant meaning was the first to come to mind; this study-test context mismatching might have impaired recollection for these targets. It has been reported in a comprehensive review about fluency (Kelley & Rhodes, 2002) that participants are more likely to rely on fluency heuristics in their memory judgments when they do not recollect the stimuli they have to make a memory judgment about. In line with this idea, we found better recollection for words encoded with their dominant meaning; and while there were no priming effects on recollection, it could be the case that for these targets, the fact that the dominant meaning was the first to come to mind during test and it matched what they encoded was enough for a recollection response, with a stronger effect than what conceptual primes could have added compared to unrelated primes.

Finally, while in Experiment 4 we did not find priming effects on recollection, priming results on familiarity in Experiment 3 are parallel to results on recollection. In Experiment 3, familiarity was increased by different meaning primes compared to same meaning primes. In other words, when primes were related to a different meaning than the encoded one, they increased familiarity compared to primes related to the encoded meaning. While this is not straightforward to interpret in the framework of the two proposed accounts, it does not go against our favoured encoding context reactivation account, since it was not recollection increased by different meaning primes.

Taken together, results reported in the four experiments included in Chapter 4 suggest that, although not as strong and consistent as repetition priming effects on familiarity, non-associative conceptual priming effects on recollection do seem to go in line with an encoding context reactivation account. At the same time, we cannot reject the idea that conceptual primes (even when they are not lexically associated with their targets) might increase item conceptual fluency.

The effects we found on familiarity seem to suggest that, for instance, when homonyms are encoded with their subordinate meaning, conceptual primes (either related to the encoded meaning or to a different meaning) affect participants' familiarity for these words, presumably by increasing item conceptual fluency. Finally, we need to acknowledge the lack of statistically significant predicted effects on recollection in Experiments 1, 3, and 4, which indicate that conceptual priming effects on recollection are subtle and more sensitive to experimental context overall compared to priming effects on familiarity, as also highlighted by Taylor and Henson (2012).

5.4. Methodological considerations, limitations and future directions

Prime awareness. We did not find prime awareness to modulate the priming effects. Although previous research reports participants' awareness of the primes decreases their likelihood to rely on fluency in their memory decisions (e.g., Jacoby & Whitehouse, 1989), our results did not change as a function of participants' awareness of primes in any experiment. This is not surprising, since research converged to the conclusion that it is not prime awareness per se influencing the reduction in priming effects on recognition memory, but participants' awareness of the prime-target overlap which leads to them correctly attribute non-mnemonic fluency to the prime and not to memory.

Fluency (mis)attribution to memory. Experimentally inducing processing fluency through repetition priming or other methods sometimes affects false alarms only and sometimes affects both hits and false alarms. Effects on hits are more difficult to interpret in the framework of non-mnemonic fluency attribution to memory, since both memory-based and perception-based fluency signals are playing a role in hit responses. As Whittlesea and colleagues highlighted in their line of research, a "clean" way to look at non-mnemonic fluency attribution to memory is to investigate effects on false alarms. This is important for our findings, given that we did not have enough false alarms trials to estimate ERPs for primed and unprimed conditions. We assumed that given the behavioural effects, with the study-test modality mismatch group not showing priming effects on false alarms, the non-mnemonic fluency attribution to memory system was switched off in this group. However, it is important for future research to compared ERPs associated with primed false alarms and ERPs associated with unprimed hits in order to be able to draw conclusions about differences between prior exposure-based or, how we called it, mnemonic fluency and non-mnemonic fluency.

EEG and DCM. The excellent temporal resolution of EEG data allows the investigation of events occurring in close temporal proximity (e.g., in our case, perceived fluency and its attribution to memory). With strong priors to inform the choice of models, DCM for evoked responses is a powerful tool to analyse EEG data given that the model inversion consists of both reconstruction of sources and their coupling architecture (David et al., 2006). One limitation of DCM for evoked responses, however, is that it is not designed to study late components (Penny et al., 2018). We looked at the 0-500ms time window and our effective connectivity results presumably capture a part of the fluency attribution to memory process. We would assume that the attribution process also consists of top-down processing. Using an entirely different paradigm than ours, but employing DCM for evoked responses, Garrido et al. (2007) showed that top-down processing reflected in backward connections only occur on late time windows. However, it can be the case that we did not find group differences on the backward connections in our DCM model because of the time window constraints; potentially, differences in backward connections strength only occur later in the epoch. Also, although our priors about the location of the sources of activity involved in the task are informed by previous research investigating similar cognitive processes, there is still a level of uncertainty in regard to the specific sources activated during our task.

Conceptual priming effects on recollection are more subtle than repetition priming effects on recognition memory and careful attention needs to be paid to the experimental design. Priming effects sometimes occurred in terms of differences between same context and different context primes, and sometimes between same/different context primes and unrelated primes. It is debatable whether an unrelated prime is the ideal 'baseline' to compare against. Research mainly investigating priming in lexical decisions found similar semantic priming effects (i.e., faster lexical decisions) when using unrelated primes, 'blank' as a primes or a string of Xs, but only when the prime-target SOA was long (1000ms) (den Heyer, Taylor & Abate, 1986). At short prime-target SOAs (~200ms, so more similar to our SOA), 'blank' was a better neutral prime than a string of Xs. (de Groot, Thomassen & Hudson, 1982; den Heyer et al., 1986). In an ERP priming study, Dien, Franklin and May (2006) found unrelated words to be better baseline primes than the word 'blank' used as a neutral prime, in terms of observed N400 attenuation effects. It could be interesting for future research to study conceptual priming effects on recognition memory using different baseline primes (e.g., the word 'blank' or a string of Xs).

In terms of the semantic relation between prime and target, it remains unclear why associative (and conceptually related) primes affect recognition memory in a similar fashion as repetition primes (e.g., Dew & Cabeza, 2013; Rajaram & Geraci, 2000). Although lexically associated primes are also conceptually related to the targets they preceded (e.g., doctor – NURSE, table – CHAIR), it appears that increasing the item fluency might potentially be a stronger signal than the reactivation of the encoded semantic context. Even if conceptual primes are not lexically associated to the targets, conceptual fluency might be sufficient to cause (mis)attribution to familiarity (e.g., in Experiments 3 and 4 from Chapter 4). Also, these effects might depend on the memory task: if familiarity-based memory is encouraged, then the fluency signal might be more relevant for the memory decision. However, future research should clarify the difference between associative and non-associative conceptual priming effects on recognition memory, potentially by including both types of primes in the same study. Another potential limitation of our conceptual priming experiments is related to the context manipulation. Yee and Thompson-Schill (2016) argued that conceptual representations are dynamic, highly dependent on a variety of factors, such as long-term experience, current task goals, recent experience, and individual differences, rather than context alone. The way we biased the encoded context of target words did not account for participants' prior experience with the words or individual differences in language abilities. Future research should ensure a better control of the encoded context manipulation. Additionally, it remains unclear whether biasing the subordinate meaning of homonyms also activates the dominant meaning, and how individual differences influence this, especially for balanced homonyms, where it is not the case that one meaning is necessarily more often occurring in language than the other meaning.

5.5. Further implications and conclusion

Overall, findings reported in this thesis suggest different mechanisms by which masked short-term priming influences familiarity-based and recollection-based memory decisions, supporting dual-process models of recognition memory. Familiarity-based memory decisions are informed mainly by item processing given that fluently processed items are more likely to be endorsed as familiar compared to less fluently processed ones, even when stimuli had not been presented in the study phase. Thus fluency does play a role in familiarity-based memory decisions; however, the fact that the difference between the proportion of primed versus unprimed trials is quite small may indicate that signals other than fluency are also important for familiarity (e.g., global matching, level of novelty). It can also be the case that familiarity is based on fluency stemming from other sources than the ones we manipulated experimentally.

On the other hand, recollection-based memory decisions seem to rely on retrieval of the encoded context of an item, although conceptual priming effects on recollection are less consistent. This supports the view that recollection-based memory is not simply strong familiarity and it is based on participants' experience of bringing back to mind something related to previous encounters of the stimuli. It remains to be elucidated by future research if or how increasing item fluency through priming might influence recollection; it is still unclear whether item fluency and retrieval of the encoded context happen in parallel, are competitive processes, or whether item fluency, especially when induced through conceptual priming, has an additive effect on remembering. Also, the encoding task might have influenced the magnitude of priming effects: when encoding is deep and recollection is relatively high, participants might rely less on perceptual fluency cues in their memory decisions overall and there might be less room for priming to influence recognition memory. At the same time, when investigating the encoding context retrieval account, it is important to ensure a deep processing of the word for participants to activate the semantic representation of the word.

The *fluency-attribution-to-memory* branch of the thesis provided insight into the relationship between processing fluency and reported familiarity for a stimulus. Behaviourally, we showed that familiarity-based memory decisions are influenced by short-term repetition priming, but this effect is modulated by the relevance of the fluency induced through priming. Interestingly, we found evidence for a change in the connectivity strength of the bottom-up connection between right PRC and right DLPFC depending on whether participants used fluency in their memory decisions or not. This indicates that familiarity-based memory decisions are a result of interactions between brain regions that "monitor" fluency and prefrontal regions involved in retrieval monitoring. Although more remains to be elucidated in terms of how the experimental context modulates conceptual priming effects on recollection, the *encoding-context-reactivation* path of the thesis provided some evidence for the mechanism by which recollection is supported by preceding targets with conceptual primes related to the encoded context. If we conceptualise recollection as cued recall, our findings suggest that a conceptual prime related to the encoded context alongside the target word form a better cue for recall than the target word alone. Finally, the differential effects of conceptual priming on familiarity and recollection highlighted the difference between the two kinds of recognition memory.

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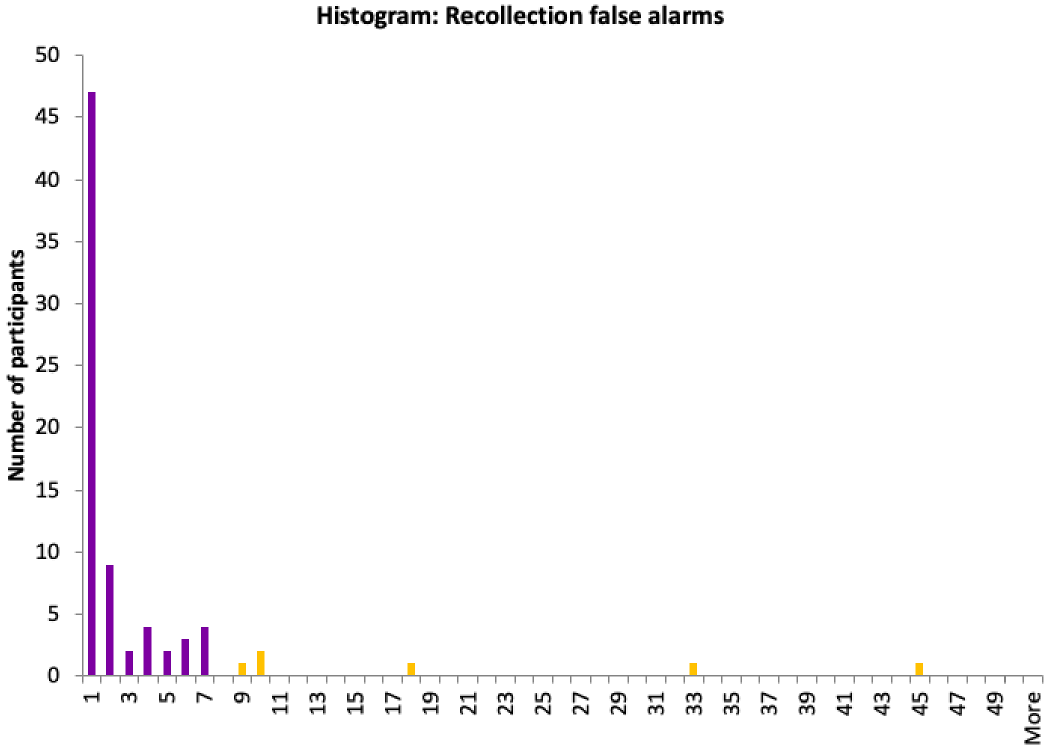
Appendix 1 – Supplementary materials for Chapter 2

Appendix 1.1. Histogram of recollection false alarms (in purple, participants who were included in the analysis; in yellow, participants who made more than Q3 + 1.5*IQR 'remember' false alarms)



Appendix 1.2. Lists of stimuli used in the experiment

List	Target	Non-matching prime
L1	CORNER	bargain
L1	ACTOR	edge
L1	SURVEY	soldier
L1	MARKET	kid
L1	CLAM	song
L1	SOUP	coat
L1	GARMENT	whiskey
L1	RUM	jury
L1	SISTER	grocery
L1	LETTUCE	singer
L1	MILITARY	pearl
L1	TEENAGER	spoon
L1	RECORD	sandwich
L1	VERDICT	sample
L1	PRICE	kin

List	Target	Non-matching prime
L2	MORAL	ring
L2	SPRING	photo
L2	PAINTING	china
L2	CURTAIN	stairs
L2	ASIA	tub
L2	SEARCH	stock
L2	TOMATO	shore
L2	CONTRACT	salad
L2	ELEVATOR	benefit
L2	CRACK	lace
L2	SINK	belief
L2	CHARITY	split
L2	SUPPLIES	seek
L2	MARRIAGE	winter
L2	SAND	lease

List	Target	Non-matching prime

L3	CANYON	nurse
L3	PATIENT	bass
L3	CELLO	salary
L3	KING	board
L3	FEE	puppy
L3	NAIL	coin
L3	TYPIST	star
L3	KITTEN	list
L3	COLUMN	clerk
L3	SILVER	routine
L3	STANDARD	empire
L3	GRAPH	career
L3	SHINE	chicken
L3	TURKEY	pattern
L3	COLLEGE	valley

List	**Target**	**Non-matching prime**
L4	DIESEL	wool
L4	AFRICA	fuel
L4	WASH	looks
L4	WIRE	speech
L4	DESSERT	cord
L4	LECTURE	orange
L4	OYSTER	grade
L4	SWALLOW	bench
L4	OVAL	swim
L4	ITCH	wax
L4	STROKE	pudding
L4	STOOL	crab
L4	PROJECT	lion
L4	APPEAL	throat
L4	FLORIDA	circle

List	**Target**	**Non-matching prime**
L5	NEWS	hose
L5	DAMAGE	type
L5	COTTON	brandy
L5	BLOUSE	puff
L5	TIMBER	critic
L5	CAPSULE	joint

L5	RELIGION	insect
L5	PEST	forest
L5	STYLE	ruin
L5	SCREAM	runner
L5	ATTIC	terror
L5	GIN	fate
L5	SPRINT	cellar
L5	TUBE	dress
L5	KNEE	tablet

List	**Target**	**Non-matching prime**
L6	BITE	brass
L6	PICTURE	apple
L6	POLISH	pilot
L6	TOY	grant
L6	MOUNTAIN	pillow
L6	COOKING	trail
L6	EQUAL	olive
L6	STUDENT	pump
L6	LOAN	mist
L6	CUSTOM	stove
L6	FILTER	culture
L6	CAPTAIN	balance
L6	MARTINI	sketch
L6	BLANKET	ball
L6	SPRAY	desk

List	**Target**	**Non-matching prime**
L7	BILL	knight
L7	BOX	coal
L7	INDIAN	tool
L7	BOMB	butter
L7	BURN	burglar
L7	CROOK	wine
L7	POTATO	warrior
L7	CLOWN	mail
L7	CHEESE	rash
L7	DIAMOND	oasis
L7	FARM	fool
L7	MANSION	rice

L7	SHIELD	palace
L7	MIRAGE	sheep
L7	DAIRY	dagger

List	**Target**	**Non-matching prime**
L8	ARROW	potty
L8	TOILET	elk
L8	REALITY	recipe
L8	BEND	tonic
L8	SKELETON	angle
L8	JAZZ	label
L8	LOOP	block
L8	STICKER	skull
L8	GLORY	fiction
L8	LOG	ballet
L8	CAKE	sunset
L8	REINDEER	stump
L8	SODA	quiver
L8	MOON	knot
L8	CEMENT	honour

List	**Target**	**Non-matching prime**
L9	CURRENCY	activity
L9	CHEAT	weather
L9	LIMB	guess
L9	HOTEL	slander
L9	EVENT	maid
L9	PANEL	oboe
L9	CLARINET	guest
L9	PURSE	mate
L9	GUN	pocket
L9	VISIT	missile
L9	STORM	siding
L9	CHANCE	cloth
L9	SILK	stick
L9	PARTNER	feast
L9	BANQUET	dollars

List	**Target**	**Non-matching prime**

L10	EMOTION	panther
L10	TASK	waist
L10	AIM	advice
L10	BELT	genius
L10	LOAD	display
L10	OPINION	depth
L10	BRAIN	lane
L10	AISLE	saloon
L10	TIGER	victory
L10	BUBBLE	tears
L10	WINNER	weight
L10	COWBOY	toil
L10	AUTO	goal
L10	WIDTH	motor
L10	SCREEN	soap

List	**Target**	**Non-matching prime**
L11	COMEDY	onion
L11	GARLIC	dock
L11	GRASS	chest
L11	WORKER	pause
L11	PENNY	bell
L11	EGYPT	jacket
L11	NOVEL	tomb
L11	DELAY	quarter
L11	PRISONER	boss
L11	MOUTH	drama
L11	PORT	poem
L11	BLAZER	root
L11	BREAST	venom
L11	ALARM	slave
L11	COBRA	braces

List	**Target**	**Non-matching prime**
L12	INDIGO	biscuit
L12	MACKEREL	impact
L12	ELEMENT	waste
L12	COOKIE	tribe
L12	MAXIMUM	economy
L12	GUITAR	nose

L12	ASHES	piano
L12	CRUSH	peach
L12	JUNGLE	soot
L12	GANG	iron
L12	TUNNEL	purple
L12	JUNK	herring
L12	ORCHARD	limit
L12	SNEEZE	club
L12	FINANCE	bridge

List	**Target**	**Non-matching prime**
L13	SEAT	amateur
L13	SUIT	mask
L13	SPORT	bone
L13	HAM	sofa
L13	APEX	formal
L13	PIZZA	tennis
L13	ROBBERY	roof
L13	TILE	summit
L13	NUTRIENT	conch
L13	TISSUE	mayor
L13	OFFICIAL	slice
L13	TRICK	meat
L13	SHELL	costume
L13	EXPERT	scheme
L13	DISGUISE	vitamin

List	**Target**	**Non-matching prime**
L14	NAPKIN	quest
L14	SUMMER	velvet
L14	STORAGE	coffee
L14	DESIRE	shed
L14	FUDGE	pack
L14	POWDER	melody
L14	ZOO	sweet
L14	HOSPITAL	fold
L14	MESSAGE	jade
L14	EMERALD	beach
L14	HUNT	surgery
L14	RHYTHM	rabbit

L14	CREAM	park
L14	TRIP	flour
L14	SATIN	letter

List	**Target**	**Non-matching prime**
L15	FUNERAL	bribe
L15	AGENCY	tobacco
L15	GADGET	duty
L15	ABUSE	wings
L15	TRAITOR	dust
L15	BROTHER	bureau
L15	ARMY	shame
L15	GLUE	grave
L15	CIGAR	notice
L15	BAY	blot
L15	SMEAR	cousin
L15	PROSE	harbour
L15	BULLETIN	tape
L15	ALLERGY	verse
L15	ANGEL	device

List	**Target**	**Non-matching prime**
L16	COURT	repeat
L16	CINEMA	hook
L16	ASHTRAY	agenda
L16	FISHING	ostrich
L16	HOLY	film
L16	MEETING	error
L16	MIMIC	claim
L16	REPLAY	creator
L16	DINNER	cross
L16	COMPUTER	vase
L16	ARTIST	plate
L16	VANILLA	crowd
L16	ANKLE	wrist
L16	STADIUM	parrot
L16	PEACOCK	cinnamon

List	**Target**	**Non-matching prime**

L17	CAMP	waves
L17	FEVER	shirt
L17	PARSLEY	fort
L17	MEASURE	rebel
L17	BARRIER	grease
L17	DIRT	unit
L17	DESIGN	herb
L17	FAT	kettle
L17	OUTCAST	statue
L17	CLOTHES	sick
L17	STEAM	cabinet
L17	SHELF	flu
L17	MUSEUM	muscle
L17	DOCTOR	fashion
L17	SPLASH	fence

List	**Target**	**Non-matching prime**
L18	BARS	plug
L18	EXCHANGE	idol
L18	METHOD	poison
L18	ENTRANCE	share
L18	FORTRESS	pond
L18	FROG	ear
L18	PIERCING	egg
L18	DRUG	signal
L18	DRAIN	excuse
L18	HERO	medieval
L18	RIVER	manner
L18	TRAFFIC	dam
L18	APOLOGY	abbey
L18	PROTEIN	gate
L18	CATHEDRAL	cell

List	**Target**	**Non-matching prime**
L19	MEANING	danger
L19	CANDY	sheet
L19	COVER	waiter
L19	LAKE	sugar
L19	RUBBISH	slide
L19	SWING	dentist

L19	DROP	zone
L19	TROUBLE	trash
L19	TIP	symbol
L19	ANGRY	swamp
L19	DRILL	scotch
L19	SAFETY	foot
L19	MILE	shelter
L19	SECTION	raise
L19	VODKA	frown

List	**Target**	**Non-matching prime**
L20	SPILL	journal
L20	BLEACH	quiet
L20	JEANS	teapot
L20	SPACE	liquid
L20	CROWN	tent
L20	PRIEST	planet
L20	DECAY	prince
L20	CHAIR	remedy
L20	HUT	leak
L20	BOIL	rust
L20	ARTICLE	sermon
L20	HONEY	rock
L20	CUSHION	patch
L20	LIBRARY	bear
L20	SOLUTION	couch

List	**Target**	**Non-matching prime**
L21	MUSCLES	spending
L21	PASSWORD	leap
L21	LENGTH	fund
L21	BUDGET	wheat
L21	COMRADE	code
L21	GAS	atlas
L21	BANK	nylon
L21	FABRIC	channel
L21	SHOWER	mood
L21	STEP	fellow
L21	TOAST	pressure
L21	SHADE	thighs

L21	ATTITUDE	height
L21	STATION	shadow
L21	GLOBE	towel

List	Target	Non-matching prime
L22	TRAVEL	inch
L22	PAYMENT	grace
L22	SHARK	site
L22	ADMIRAL	file
L22	YARD	jaguar
L22	GOLF	rail
L22	PRAYER	page
L22	RIOT	ability
L22	HANDLE	badge
L22	LEOPARD	commander
L22	STORE	par
L22	LOCATION	rent
L22	COURAGE	airport
L22	TALENT	whale
L22	CHAPTER	uprising

List	Target	Non-matching prime
L23	BEAUTY	festival
L23	JEWEL	plane
L23	CREED	logic
L23	BEER	linen
L23	PARADE	organ
L23	BET	rose
L23	BRONZE	smudge
L23	LAUNDRY	jog
L23	DROUGHT	branch
L23	TRAIN	copper
L23	LEAF	race
L23	STOMACH	odds
L23	WALK	foam
L23	INK	famine
L23	NONSENSE	gold

List	Target	Non-matching prime

L24	TRUMPET	proof
L24	BOUTIQUE	horn
L24	SINGLE	tuna
L24	FRIGHT	anatomy
L24	TAXI	seed
L24	HURT	gift
L24	DEFEAT	shop
L24	TRUTH	loss
L24	SPROUT	camel
L24	RIBBON	fare
L24	HIT	blame
L24	CACTUS	whip
L24	SIREN	widow
L24	SALMON	ghost
L24	MEDICINE	flute

List	**Target**	**Non-matching prime**
L25	HOWL	lover
L25	CHIEF	hamper
L25	SKI	sell
L25	PAIN	master
L25	SPOUSE	shock
L25	AUCTION	carpet
L25	SPINACH	guts
L25	BASKET	lodge
L25	VACUUM	skin
L25	RAINBOW	guide
L25	LEADER	kale
L25	WRINKLES	temple
L25	BOTHER	wolf
L25	BLOOD	hue
L25	WORSHIP	fuss

List	**Target**	**Non-matching prime**
L26	BRICK	dove
L26	GLASS	flap
L26	CHORE	slab
L26	SEAL	surf
L26	SALIVA	wedding
L26	PIGEON	mirror

L26	CLOSET	burden
L26	MILL	tail
L26	TOUCH	image
L26	REAR	fingers
L26	ITEM	drawers
L26	TIDE	piece
L26	BRIDE	tank
L26	VISION	glands
L26	BATTLE	factory

List	**Target**	**Non-matching prime**
L27	ATHLETE	cereal
L27	VOTE	choir
L27	DAISY	zebra
L27	RELATIVE	raisins
L27	BANANA	marble
L27	STUDY	quick
L27	DONKEY	poppy
L27	OATMEAL	focus
L27	LICE	player
L27	GRANITE	stem
L27	GRAIN	flea
L27	SPEED	coconut
L27	CORN	uncle
L27	POT	maize
L27	MUSIC	debate

List	**Target**	**Non-matching prime**
L28	CRYSTAL	booth
L28	STALL	yellow
L28	RISK	metal
L28	SMELL	nerves
L28	POET	gamble
L28	PLASTIC	poster
L28	BROWN	rifle
L28	FLIGHT	bird
L28	TENSION	author
L28	COWARD	sweat
L28	SCHEDULE	leaves
L28	MAGAZINE	ruby

L28	CALM	plan
L28	BULLET	rubber
L28	FRAME	peace

List	**Target**	**Non-matching prime**
L29	ENEMY	jug
L29	TRUCK	uniform
L29	FANTASY	roach
L29	FINESSE	myth
L29	MEADOW	illness
L29	KNIFE	elm
L29	MATERIAL	axe
L29	JAR	sandals
L29	OUTFIT	cough
L29	TOES	tact
L29	DISEASE	hate
L29	MIRACLE	pasture
L29	OAK	tyre
L29	SMOKE	magic
L29	BEETLE	canvas

List	**Target**	**Non-matching prime**
L30	MEMO	blaze
L30	WARNING	crew
L30	WALLET	taste
L30	FLAVOUR	note
L30	SKILL	cave
L30	CEILING	craft
L30	KISS	relief
L30	TEAM	wall
L30	FEATHERS	caution
L30	ASPIRIN	oath
L30	FLAME	prestige
L30	FAME	quilt
L30	ELECTRON	leather
L30	OPENING	nucleus
L30	PLEDGE	lipstick

List	**Target**	**Non-matching prime**

L31	COCOA	extra
L31	FLOWERS	engineer
L31	MISTAKE	steel
L31	PLOT	escape
L31	REWARD	vehicle
L31	BICYCLE	theatre
L31	DENIM	acre
L31	DRIVER	cashmere
L31	TICKET	fault
L31	BLADE	rider
L31	BUILDER	chocolate
L31	SOIL	medal
L31	STAGE	bush
L31	EXCESS	officer
L31	FREEDOM	plant

List	**Target**	**Non-matching prime**
L32	DRAGON	fitness
L32	WORKOUT	tenor
L32	LUXURY	trunk
L32	THUNDER	pipe
L32	MOSQUITO	lobby
L32	TOOTH	media
L32	DISH	rain
L32	SUITCASE	lamp
L32	BULB	monster
L32	OCEAN	cup
L32	SPOKE	comfort
L32	WRENCH	enamel
L32	OPERA	coast
L32	LOUNGE	wheel
L32	REPORTER	bee

Appendix 1.3. Code for generating the auditory stimuli

```
#!/bin/bash

# Script to read words from text files and record ttl using mac say.
dowrite=1
cd words
for word in `cat ../pairs.txt`; do
        echo $word
        # Speak:
        if [ "$dowrite" = "0" ]; then
                say -v Daniel -r 200 $word
        fi
        # Write to file:
        if [ "$dowrite" = "1" ]; then
                # Write:
                #say -v Daniel -r 200 $word
                echo "Writing to aiff words/$word"
                say -v Daniel -r 200 -o $word.aiff $word
        fi
done
cd ..
```

Appendix 1.4. R/K instructions

Participants were explained that they will see one word at a time on the screen and they will first have to indicate if the word was presented in Task 1 or not (old/new). Then, if they respond 'old' they have to decide if they remember the word or if it is familiar. A familiar word is one they are sure it has been presented in Task 1, but they cannot remember anything else, so they only recognise the word itself; on the other hand they were told to choose 'remember' when they can bring back to mind something IN ADDITION to the word itself, about its presentation in Task 1 – it can be a mental image they created, something they thought of when they saw the word in Task 1, another word that came before or after in the study list, if the word was presented at the beginning or towards the end of the list, their response to the word (i.e., if they found it interesting or not), basically anything that they can recall from Task 1 about the word. Also, they were given the real life example of familiarity/remember with a face we can recognise on the street (strong FAMILIARITY - we know for sure we met the person before) but we cannot recollect the name or where we met etc. After an active search we might eventually REMEMBER the name or the context we met etc. In the case of words, they should use 'familiar' when they know the word was presented in Task 1 but they cannot remember any detail/aspect about the presentation of the word. They should use 'remember' when they can recollect something about Task 1 presentation. After these explanations, participants completed the practice block where they could also read the same instructions that were given verbally by the experimenter. After the completion of the practice block the experimenter checked if participants understood the familiar/remember instructions. So they were asked what is the difference between the two response options, when they would choose 'familiar' and when they would choose 'remember'. Here, if they answer 'familiar' is weak memory/they are not very sure & 'remember' is strong memory/high certainty, then it was stressed that they can feel strong familiarity without recollecting any details. So it was emphasised that the distinction between familiar/remember is not strength of memory or certainty, but they should only choose 'remember' when they can actually bring back to mind something about the first presentation of the word (in Task 1).

Appendix 1.5. Additional analyses

Response times

For completeness and for consistency with other papers in the literature, a 3 x 4 (group by response) ANOVA was performed on median RTs extracted for K hits, R hits, correct rejections and misses. The main effect of response was significant ($F(3,201) = 37.01$, $p < .001$, partial $\eta^2 = .356$). There was no significant main effect of group ($F(2,67) = 2.75$, $p = .071$, partial $\eta^2 = .076$) and no significant interaction group x response ($F(6,396) = 1.41$, $p = .212$, partial $\eta^2 = .040$). Response times for subsequently-R "old" responses were significantly faster than both misses ($t(1,69) = 3.97$, $p < .001$) and subsequently-K "old" responses ($t(1,69) = 9.87$, $p < .001$), correct rejections were significantly faster than both misses ($t(1,69) = 5.38$, $p < .001$) and subsequently-K "old" responses ($t(1,69) = 8.62$, $p < .001$) and misses were significantly faster than subsequently-K "old" responses ($t(1,69) = 3.68$, $p < .001$), with a Bonferroni-corrected significance threshold of .008. These results are in line with previous studies (e.g., Woollams et al., 2008).

Statistical analyses on iK responses

A 3 x 2 x 2 (group by priming by study status) on proportions of familiarity responses (calculated under independence assumptions as $iK=K/(1-R)$ (Yonelinas & Jacoby, 1995)) showed a significant main effect of study status (simply indicating more iK responses to studied than to unstudied items) and a significant main effect of priming ($F(1, 67) = 5.88$, $p = .018$, partial $\eta^2 = .081$), with a higher proportion of familiarity (iK) responses to primed compared to unprimed words. Although the interaction priming x group was not significant ($F(2, 136) = .025$, $p = .975$, partial $\eta^2 = .001$), in light of the predicted patterns of results, planned contrasts were conducted to look at priming effects in each group. In the Visual group, a 2 x 2 (priming by study status) ANOVA showed a nearly significant main effect of priming ($F(1, 23) = 4.14$, $p = .053$, partial $\eta^2 = .153$) in the predicted direction on both hits and false alarms. In the Auditory group, there were no significant effect of priming ($F(1,22) = .92$, $p = .349$, partial $\eta^2 = .040$) or significant interaction priming by study status ($F(1,22) = .18$, $p = .675$, partial $\eta^2 = .008$). In the Auditory/Visual group, there was no significant main effect of priming (F(1, 22) = 2.50, p = .128, partial η^2= .102), although the difference was in the predicted direction.

Response	Auditory study group				Visual study group				Auditory/Visual group			
	Studied		Unstudied		Studied		Unstudied		Studied		Unstudied	
	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed
iK	0.55 (0.22)	0.53 (0.23)	0.09 (0.10)	0.08 (0.06)	0.43 (0.22)	0.40 (0.23)	0.07 (0.06)	0.05 (0.04)	0.50 (0.24)	0.47 (0.23)	0.12 (0.11)	0.10 (0.08)

An analysis of study modality by priming in the Auditory/Visual group showed a main effect of study modality (F(1,22) = 9.28, p = .006, partial η^2= .297) on iK responses, with more "familiar" responses given to words presented in the visual modality during study compared to words presented in the auditory condition. There were no significant main effect of priming (F(1,22) = .87, p = .362, partial η^2= .038) or significant interaction study modality x priming (F(1,22) = .10, p = .760, partial η^2= .004).]

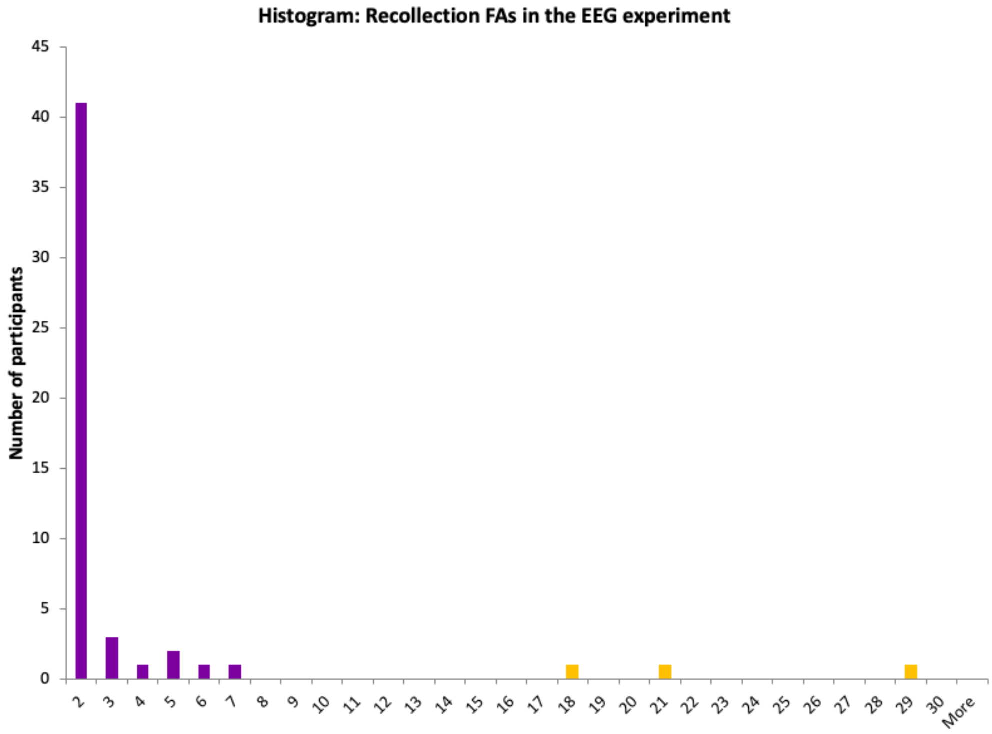
<u>Statistical analyses on a sub-sample of participants who were completely unaware of or could not read any of the prime words</u>

Visual group (N = 19), Auditory group (N = 23), AV group (N = 22). The 3 x 2 x 2 (group by priming by study status) ANOVA on "old" responses showed a main effect of study status (simply indicating that participants made more "old" responses to studied items than to unstudied ones), a main effect of priming (F(1,61) = 887.47, p < .001, partial η^2= .936) with significantly more "old" responses to primed compared to unprimed words, and a main effect of group (F(2,61) = 4.64, p = .013, partial η^2= .132). Follow-up Bonferroni-corrected post-hoc tests on the main effect of group showed participants in the Visual group made significantly fewer "old" responses than both those in the Auditory group (p = .020) and those in the Auditory/Visual (p = .045), but there was no significant difference between the Auditory and Auditory/Visual groups (p = 1). Even though the interaction group x priming was not significant (F(2,123) = 1.89, p = .160, partial η^2= .058), to test for the predicted pattern of priming effects across groups, separate 2 x 2 (priming by study status) ANOVAs were conducted in each group. They showed significant priming effects in the predicted direction in the Visual group (F(1,28) = 5.92, p = .026, partial η^2 = .247) and in the Auditory/Visual group (F(1,21) = 6.76, p = .017, partial η^2= .243), but not in the Auditory group (F(1,22) = .09, p = .770, partial η^2 = .004). The interactions between study status x priming were not significant in any of the three groups (Visual (F(1,18) = 3.42, p = .081, partial η^2 = .160), Auditory/Visual (F(1,21) = .01, p = 924, partial η^2 < .001), Auditory (F(1,22) = 1,15, p = .296, partial η^2 = .050).

A 3 x 2 x 2 (group by priming by study status) on proportions of K responses showed a significant main effect of study status (simply showing that participants made more K responses to studied items than to unstudied ones) and a significant main effect of priming ($F(1, 61) = 9.28$, $p = .003$, partial $\eta^2 = .132$), with a higher proportion of K responses to primed compared to unprimed words. Although the interaction group x priming was not significant ($F(2, 123) = .39$, $p = .676$, partial $\eta^2 = .013$), in light of the predicted patterns of results, planned contrasts were conducted to look at priming effects in each group. Separate 2 x 2 (priming x study status) ANOVAs were run in each group. In both the Visual group ($F(1, 19) = 6.34$, $p = .021$, partial $\eta^2 = .269$) and the Auditory/Visual group ($F(1, 21) = 4.53$, $p = .045$, partial $\eta^2 = .178$), there was a significant priming effect in the predicted direction across study status. In the Auditory group, there was no significant main effect of priming ($F(1, 22) = .91$, $p = .351$, partial $\eta^2 = .041$) or significant interaction between priming and study status ($F(1, 22) = .24$, $p = .630$, partial $\eta^2 = .011$). The 3 x 2 (group by priming) ANOVA on R hits did not yield any significant effects.

Appendix 2 – Supplementary materials for Chapter 3

Appendix 2.1. Histogram of recollection false alarms across the two groups



Appendix 2.2. List of stimuli used in the experiment

List	Target	Non-matching prime
L1	ANECDOTE	battle
L1	BRONZE	chair
L1	AUCTION	chief
L1	TUNIC	bronze
L1	MEADOW	boutique
L1	BOUTIQUE	crook
L1	CROOK	tunic
L1	LOG	occasion
L1	CHIEF	entrance
L1	ENTRANCE	auction
L1	OCCASION	breast
L1	ANTIQUE	meadow
L1	BREAST	anecdote
L1	CHAIR	antique
L1	BATTLE	log

List	Target	Non-matching prime
L2	CAT	theme
L2	THEME	actor
L2	MYSTIC	skate
L2	COTTON	suitcase
L2	YARD	cat
L2	ACTOR	bay
L2	SKATE	powder
L2	TROUBLE	cotton
L2	SUITCASE	flicker
L2	TICKET	yard
L2	FLICKER	charity

L2	POWDER	mystic
L2	CHARITY	trouble
L2	BAY	spring
L2	SPRING	ticket

List	**Target**	**Non-matching prime**
L3	EXPRESS	chrome
L3	CHROME	tiger
L3	ROBBERY	artist
L3	PURSE	educator
L3	BICYCLE	spray
L3	ARTIST	bicycle
L3	EDUCATOR	liberty
L3	CLARINET	tension
L3	LIBERTY	cello
L3	TENSION	institute
L3	CELLO	robbery
L3	TIGER	purse
L3	SPRAY	express
L3	INSTITUTE	mimic
L3	MIMIC	clarinet

List	**Target**	**Non-matching prime**
L4	COVER	infant
L4	INFANT	ashes
L4	MALL	cookie
L4	SINK	clown
L4	CLOVER	sink
L4	COOKIE	spinach
L4	CLOWN	clover
L4	ASHES	carrot
L4	LILY	cover
L4	SPINACH	semester
L4	COMEDY	apology

L4	SECTION	mall
L4	APOLOGY	section
L4	SEMESTER	lily
L4	CARROT	comedy

List	**Target**	**Non-matching prime**
L5	WRINKLES	supper
L5	DROP	winner
L5	MARRIAGE	seal
L5	SOIL	vodka
L5	MAXIMUM	wrinkles
L5	TRAIN	knife
L5	WINNER	drop
L5	SEAL	maximum
L5	CHERRY	lotion
L5	CUSTOM	cherry
L5	LOTION	flora
L5	KNIFE	custom
L5	FLORA	marriage
L5	VODKA	soil
L5	SUPPER	train

List	**Target**	**Non-matching prime**
L6	WORKOUT	bulb
L6	PARAGRAPH	opera
L6	SCHOLAR	safety
L6	OPERA	receipt
L6	OVEN	scholar
L6	RAY	workout
L6	BULB	novel
L6	LEAF	cloud
L6	NOVEL	truth
L6	CURRENCY	paragraph
L6	TRUTH	humanity

L6	HUMANITY	currency
L6	CLOUD	leaf
L6	RECEIPT	oven
L6	SAFETY	ray

List	**Target**	**Non-matching prime**
L7	SUBMARINE	tie
L7	PEACEFUL	material
L7	TOILET	submarine
L7	PARSLEY	peaceful
L7	PUZZLE	official
L7	MATERIAL	toilet
L7	COLLEGE	rural
L7	CRUSH	sleeve
L7	RURAL	balloon
L7	DESIGN	parsley
L7	SLEEVE	pony
L7	BALLOON	design
L7	TIE	puzzle
L7	OFFICIAL	crush
L7	PONY	college

List	**Target**	**Non-matching prime**
L8	MIRACLE	rhythm
L8	GIN	toy
L8	CHANCE	gin
L8	STICKER	tunnel
L8	RHYTHM	boundary
L8	RADIO	smart
L8	GRAPH	miracle
L8	TUNNEL	message
L8	ASIA	graph
L8	GRAVITY	asia
L8	BOUNDARY	chance

L8	INDIGO	sticker
L8	SMART	radio
L8	TOY	gravity
L8	MESSAGE	indigo

List	**Target**	**Non-matching prime**
L9	TEENAGER	fever
L9	MARTINI	driver
L9	FEVER	chore
L9	VACATION	native
L9	NATIVE	martini
L9	VEST	harp
L9	GLORY	division
L9	REFLEX	handle
L9	HANDLE	vacation
L9	HOLY	reflex
L9	MINUTE	holy
L9	DIVISION	vest
L9	HARP	teenager
L9	DRIVER	glory
L9	CHORE	minute

List	**Target**	**Non-matching prime**
L10	GALAXY	member
L10	FAT	flame
L10	GRASS	lazy
L10	BUBBLE	discovery
L10	LAZY	glacier
L10	SMOKE	galaxy
L10	GLACIER	belt
L10	FLAME	fat
L10	DISCOVERY	polish
L10	POLISH	flavour
L10	SWING	smoke

L10	SPEED	swing
L10	BELT	grass
L10	FLAVOUR	speed
L10	MEMBER	bubble

List	**Target**	**Non-matching prime**
L11	GYM	frame
L11	ASPARAGUS	candle
L11	BORN	asparagus
L11	GARLIC	sport
L11	PATIENT	loan
L11	CANDLE	gym
L11	FRAME	born
L11	ARTICLE	harmony
L11	HARMONY	golf
L11	SPORT	fantasy
L11	VERTICAL	beer
L11	GOLF	article
L11	BEER	patient
L11	FANTASY	vertical
L11	LOAN	garlic

List	**Target**	**Non-matching prime**
L12	NYMPH	skirt
L12	DOCTOR	tweed
L12	AGILITY	hen
L12	COLUMN	doctor
L12	SNAIL	verdict
L12	HEN	admiral
L12	ADMIRAL	moon
L12	TWEED	nymph
L12	GLITTER	agility
L12	MOON	self
L12	STATION	column

L12	SELF	station
L12	SKIRT	truck
L12	TRUCK	glitter
L12	VERDICT	snail

List	**Target**	**Non-matching prime**
L13	OBJECT	innate
L13	DEPOSIT	professor
L13	FROG	method
L13	FLOWERS	chapter
L13	TOUCH	nectar
L13	CHAPTER	cavern
L13	PROFESSOR	urban
L13	NECTAR	deposit
L13	METHOD	touch
L13	INNATE	frog
L13	CUSHION	surprise
L13	CAVERN	object
L13	LOAD	flowers
L13	URBAN	cushion
L13	SURPRISE	load

List	**Target**	**Non-matching prime**
L14	PASSWORD	luxury
L14	WALK	granite
L14	SMELL	origin
L14	LUXURY	saliva
L14	VACUUM	dragon
L14	SAND	jaw
L14	JAW	pioneer
L14	ORIGIN	sand
L14	GRANITE	seat
L14	BOIL	vacuum
L14	SALIVA	prayer

L14	DRAGON	boil
L14	SEAT	password
L14	PIONEER	walk
L14	PRAYER	smell

List	**Target**	**Non-matching prime**
L15	ACCOUNT	bend
L15	RUM	robin
L15	REWARD	syllable
L15	LIP	sprout
L15	ROBIN	shield
L15	WARNING	laundry
L15	SPROUT	merit
L15	MERIT	abundant
L15	LAUNDRY	limousine
L15	SYLLABLE	captain
L15	LIMOUSINE	account
L15	ABUNDANT	lip
L15	CAPTAIN	warning
L15	BEND	reward
L15	SHIELD	rum

List	**Target**	**Non-matching prime**
L16	BELLY	graceful
L16	GRACEFUL	web
L16	KING	shelf
L16	KITTEN	traveller
L16	SOLUTION	staff
L16	SHELF	kitten
L16	STAFF	ocean
L16	CEMENT	belly
L16	WEB	relative
L16	RELATIVE	mountain
L16	MOUNTAIN	skeleton

L16	REAR	cement
L16	SKELETON	rear
L16	TRAVELLER	solution
L16	OCEAN	king

List	**Target**	**Non-matching prime**
L17	SHOT	tube
L17	PARADE	canyon
L17	TUBE	leopard
L17	ITEM	grain
L17	PASSION	item
L17	LEOPARD	parade
L17	DISGUISE	diamond
L17	BULLETIN	passion
L17	DIAMOND	shot
L17	SEGMENT	giant
L17	GRAIN	bulletin
L17	GIANT	segment
L17	LEMON	disguise
L17	CANYON	scissors
L17	SCISSORS	lemon

List	**Target**	**Non-matching prime**
L18	CHAMPION	warmth
L18	JAR	drain
L18	BROWN	champion
L18	CONTRACT	brown
L18	PROSE	joke
L18	WARMTH	timber
L18	STAGE	contract
L18	SADDLE	delay
L18	ADORN	oak
L18	JOKE	jar
L18	DRAIN	crown

L18	OAK	saddle
L18	DELAY	adorn
L18	TIMBER	stage
L18	CROWN	prose

List	**Target**	**Non-matching prime**
L19	KITE	attitude
L19	SELECTION	riot
L19	HEALTH	kite
L19	FREEDOM	selection
L19	SMEAR	tea
L19	MUSEUM	health
L19	SISTER	freedom
L19	POLITE	vanilla
L19	TAXI	polite
L19	HOSPITAL	sister
L19	TEA	museum
L19	RIOT	smear
L19	ATTITUDE	reminder
L19	VANILLA	taxi
L19	REMINDER	hospital

List	**Target**	**Non-matching prime**
L20	WALLET	shade
L20	RECORD	stall
L20	SUPPLIES	wallet
L20	SHADE	turkey
L20	STORAGE	project
L20	CANDY	blanket
L20	PROJECT	storage
L20	VISION	candy
L20	SKILL	nail
L20	TURKEY	supplies
L20	STALL	desire

L20	BLANKET	record
L20	DESIRE	citizen
L20	NAIL	skill
L20	CITIZEN	vision

List	**Target**	**Non-matching prime**
L21	DEFEAT	corn
L21	HERO	knee
L21	CLAM	vote
L21	MEMO	link
L21	NONSENSE	banana
L21	HELMET	memo
L21	APEX	defeat
L21	KNEE	clam
L21	VOTE	ceiling
L21	BANANA	arrow
L21	CORN	hero
L21	CEILING	allergy
L21	LINK	helmet
L21	ARROW	apex
L21	ALLERGY	nonsense

List	**Target**	**Non-matching prime**
L22	DREAM	student
L22	GADGET	reality
L22	BROTHER	finesse
L22	ACADEMY	budget
L22	FINESSE	dozen
L22	TILE	dream
L22	SUIT	protein
L22	COMPUTER	brother
L22	PROTEIN	magnet
L22	STUDENT	suit
L22	BUDGET	tile

L22	MAGNET	shower
L22	SHOWER	gadget
L22	DOZEN	computer
L22	REALITY	academy

List	**Target**	**Non-matching prime**
L23	EGYPT	meeting
L23	ALLEY	heaven
L23	ASHTRAY	pyramid
L23	MEETING	ashtray
L23	OYSTER	glass
L23	TASK	painting
L23	PAINTING	alley
L23	HEAVEN	reporter
L23	PYRAMID	traffic
L23	ABYSS	egypt
L23	EMBRACE	task
L23	TRAFFIC	oyster
L23	LIMB	abyss
L23	REPORTER	limb
L23	GLASS	embrace

List	**Target**	**Non-matching prime**
L24	SHARK	wire
L24	DROUGHT	squirrel
L24	COMRADE	shark
L24	BASKET	beaver
L24	ANKLE	comrade
L24	DRUG	cable
L24	AGENCY	basket
L24	BLEACH	drought
L24	WIRE	agency
L24	CABLE	payment
L24	TOPIC	ankle

L24	BEAVER	drug
L24	SQUIRREL	spell
L24	SPELL	topic
L24	PAYMENT	bleach

List	**Target**	**Non-matching prime**
L25	RAINBOW	practical
L25	PATH	alarm
L25	ETERNITY	pollen
L25	CROCODILE	rainbow
L25	RIB	crocodile
L25	ALARM	rib
L25	CONE	piercing
L25	WIZARD	cone
L25	OVAL	wizard
L25	POLLEN	path
L25	PRACTICAL	penny
L25	PIERCING	loop
L25	OUTFIT	oval
L25	PENNY	eternity
L25	LOOP	outfit

List	**Target**	**Non-matching prime**
L26	GODDESS	stew
L26	STADIUM	butterfly
L26	NECK	mill
L26	BRUSH	admission
L26	BUTTERFLY	thirsty
L26	SUMMER	brush
L26	THIRSTY	goddess
L26	STEW	neck
L26	FABRIC	evolution
L26	SPHERE	canal
L26	EVOLUTION	summer

L26	CANAL	flash
L26	MILL	fabric
L26	FLASH	sphere
L26	ADMISSION	stadium

List	**Target**	**Non-matching prime**
L27	DISTANCE	kiss
L27	CATHEDRAL	diesel
L27	KISS	fishing
L27	STOCKING	package
L27	FISHING	builder
L27	BUILDER	distance
L27	RECTANGLE	coach
L27	PICTURE	appeal
L27	PACKAGE	magician
L27	MAGICIAN	rectangle
L27	APPEAL	pianist
L27	FUDGE	stocking
L27	PIANIST	picture
L27	DIESEL	fudge
L27	COACH	cathedral

List	**Target**	**Non-matching prime**
L28	EXCHANGE	steam
L28	EXPERT	crack
L28	RYE	lecture
L28	STEAM	rye
L28	FEE	single
L28	SINGLE	region
L28	FARM	charge
L28	ATTIC	farm
L28	CRACK	fee
L28	CREAM	attic
L28	CHARGE	jungle

L28	JUNGLE	expert
L28	REGION	cream
L28	LECTURE	tornado
L28	TORNADO	exchange

List	**Target**	**Non-matching prime**
L29	PARTNER	welcome
L29	BAT	meaning
L29	CORRIDOR	partner
L29	THREAD	courage
L29	WELCOME	bat
L29	BRIDE	astronomy
L29	ADDITION	indian
L29	CLOTHES	wrench
L29	INDIAN	minister
L29	MEANING	addition
L29	COURT	bride
L29	ASTRONOMY	court
L29	COURAGE	clothes
L29	WRENCH	thread
L29	MINISTER	corridor

List	**Target**	**Non-matching prime**
L30	TOAST	survey
L30	STANDARD	dessert
L30	SURVEY	feathers
L30	STOMACH	standard
L30	DESSERT	religion
L30	PLASTIC	magazine
L30	MEASURE	plastic
L30	TOOTH	drill
L30	BASEMENT	toast
L30	DRILL	measure
L30	JOY	basement

L30	RELIGION	stomach
L30	MAGAZINE	athlete
L30	ATHLETE	tooth
L30	FEATHERS	joy

List	**Target**	**Non-matching prime**
L31	RISK	dairy
L31	HAZARD	coward
L31	COWARD	ham
L31	CLEVER	bottle
L31	CLOSET	refresh
L31	DAIRY	clever
L31	REFRESH	bill
L31	CIGAR	barrier
L31	LEADER	mirage
L31	BOTTLE	hazard
L31	BARRIER	cigar
L31	BILL	locker
L31	LOCKER	leader
L31	MIRAGE	closet
L31	HAM	risk

List	**Target**	**Non-matching prime**
L32	INTERIOR	potato
L32	DUCHESS	salmon
L32	BLAZER	banker
L32	AERIAL	pest
L32	POTATO	opening
L32	LOCATION	episode
L32	DEED	location
L32	SPICY	globe
L32	BANKER	camp
L32	EPISODE	spicy
L32	OPENING	deed

L32	CAMP	duchess
L32	SALMON	aerial
L32	GLOBE	blazer
L32	PEST	interior

List	**Target**	**Non-matching prime**
L33	INTERVIEW	pendulum
L33	SHINY	zenith
L33	SILK	cheese
L33	BANQUET	interview
L33	CHEESE	calm
L33	PLEDGE	mile
L33	MANSION	plot
L33	JUNK	florida
L33	PENDULUM	silk
L33	FLORIDA	mansion
L33	CALM	lice
L33	MILE	shiny
L33	PLOT	banquet
L33	LICE	pledge
L33	ZENITH	junk

List	**Target**	**Non-matching prime**
L34	DONKEY	motion
L34	HOTEL	donkey
L34	WORSHIP	damage
L34	FREEZE	machine
L34	PRIEST	hotel
L34	ANGEL	arrival
L34	CURIOSITY	worship
L34	DAMAGE	priest
L34	STORM	curiosity
L34	MACHINE	angel
L34	MOTION	cobra

L34	PIGEON	birth
L34	BIRTH	storm
L34	COBRA	pigeon
L34	ARRIVAL	freeze

List	**Target**	**Non-matching prime**
L35	DIFFUSION	daisy
L35	INVENTION	hunt
L35	TRAITOR	glue
L35	SWALLOW	detective
L35	FUNERAL	invention
L35	DETECTIVE	panel
L35	PANEL	funeral
L35	SCREEN	traitor
L35	MORAL	screen
L35	TOMATO	moral
L35	DAISY	fog
L35	FOG	swallow
L35	NEWS	tomato
L35	HUNT	diffusion
L35	GLUE	news

List	**Target**	**Non-matching prime**
L36	MOSQUITO	brain
L36	OUTCAST	session
L36	CRYSTAL	honey
L36	FLIGHT	nephew
L36	JAZZ	outcast
L36	VISIT	jazz
L36	INK	mild
L36	TELEGRAPH	mosquito
L36	HONEY	visit
L36	NEPHEW	telegraph
L36	MILD	bars

L36	BRAIN	market
L36	SESSION	ink
L36	BARS	flight
L36	MARKET	crystal

List	**Target**	**Non-matching prime**
L37	ELEMENT	ski
L37	ELEPHANT	stool
L37	BEAUTY	space
L37	BET	beauty
L37	PIZZA	sage
L37	SAGE	elephant
L37	SKI	bet
L37	GARMENT	dough
L37	DOUGH	shepherd
L37	SHEPHERD	africa
L37	FAME	pizza
L37	SPACE	garment
L37	STOOL	element
L37	AFRICA	amuse
L37	AMUSE	fame

List	**Target**	**Non-matching prime**
L38	GINGER	price
L38	DRUM	fox
L38	PORTION	decay
L38	FOX	shell
L38	SILENCE	peacock
L38	SHELL	nutrient
L38	STEP	drum
L38	ZOO	bin
L38	NUTRIENT	zoo
L38	CONTENT	step
L38	DECAY	ginger

L38	ASSEMBLE	silence
L38	PEACOCK	portion
L38	PRICE	content
L38	BIN	assemble

List	**Target**	**Non-matching prime**
L39	FOREIGNER	schedule
L39	EVENT	talent
L39	CINEMA	income
L39	CURTAIN	event
L39	MUSICIAN	lobster
L39	TEAM	musician
L39	ECHO	curtain
L39	LETTUCE	republic
L39	SCHEDULE	echo
L39	CHIN	cinema
L39	INCOME	emotion
L39	TALENT	lettuce
L39	EMOTION	team
L39	LOBSTER	foreigner
L39	REPUBLIC	chin

List	**Target**	**Non-matching prime**
L40	INTENSE	turtle
L40	R hitsYME	electron
L40	SNEEZE	tissue
L40	THUNDER	replay
L40	TURTLE	avenue
L40	REPLAY	cactus
L40	OPINION	library
L40	ELECTRON	scream
L40	AVENUE	corner
L40	SCREAM	straw
L40	LIBRARY	sneeze

L40	TISSUE	intense
L40	STRAW	R hitsyme
L40	CORNER	thunder
L40	CACTUS	opinion

Appendix 1.3. Additional analyses

Statistical analyses on iK responses

A 2 x 2 x 2 (group by priming by study status) on proportions of familiarity responses (calculated under independence assumptions as iK=K/(1-R) (Yonelinas & Jacoby, 1995)) showed a significant main effect of study status (simply indicating more iK responses to studied than to unstudied items) and a significant main effect of priming ($F(1, 48) = 16.05$, $p < .001$, partial $\eta^2 = .251$), with a higher proportion of familiarity (iK) responses to primed compared to unprimed words. Although the interaction priming x group was not significant ($F(1, 48) = 2.61$, $p = .113$, partial $\eta^2 = .052$), in light of the predicted patterns of results, planned contrasts were conducted to look at priming effects in each group. In the Visual group, a 2 x 2 (priming by study status) ANOVA showed a significant main effect of priming ($F(1, 23) = 11.95$, $p = .002$, partial $\eta^2 = .342$) in the predicted direction on both hits and false alarms. In the Auditory group, the main effect of priming on iK responses was nearly significant ($F(1,25) = 3.97$, $p = .057$, partial $\eta^2 = .137$).

Response	Auditory study group				Visual study group			
	Studied		Unstudied		Studied		Unstudied	
	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed	Primed	Unprimed
iK	0.63 (0.18)	0.61 (0.17)	0.06 (0.06)	0.06 (0.06)	0.74 (0.17)	0.71 (0.18)	0.08 (0.08)	0.06 (0.05)

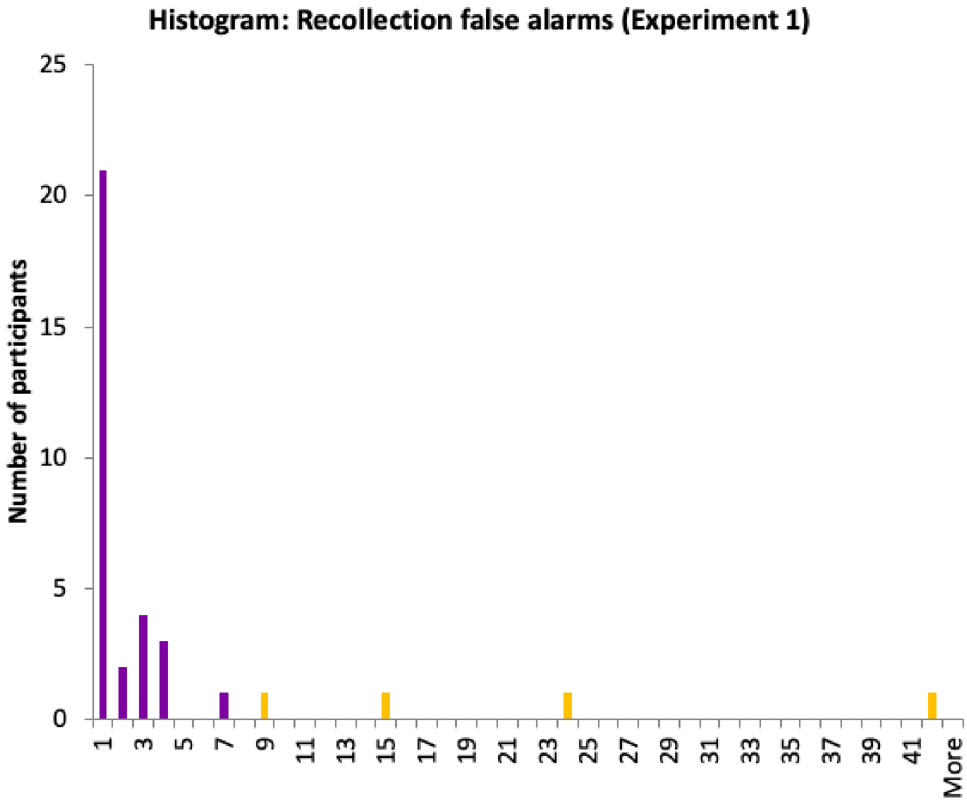
Statistical analyses on a sub-sample of participants who were completely unaware of or could not read any of the prime words

Visual group (*N* = 17) and Auditory group (*N* = 18). The 3 x 2 x 2 (group by priming by study status) ANOVA on "old" responses showed a main effect of priming ($F(1,33) = 12.15$, $p = .001$, partial $\eta^2 = .269$) with significantly more "old" responses to primed compared to unprimed words, a main effect of group ($F(1,33) = 9.36$, $p = .004$, partial $\eta^2 = .221$), and a main effect of study status (simply indicating that participants made more "old" responses to studied items than to unstudied ones). Furthermore, the interaction group x study status was significant ($F(1,33) = 6.84$, $p = .013$, partial $\eta^2 = .172$), associated with the group difference in memory performance. The interactions study status x priming ($F(1,33) < .001$, $p = .984$, partial $\eta^2 < .001$) and study status x priming x group ($F(1,33) = 1.97$, $p = .169$, partial $\eta^2 = .056$) were not significant. Even though the interaction group x priming was not significant either ($F(1,33) = 3.24$, $p = .081$, partial $\eta^2 = .089$), to test for the predicted pattern of priming effects across groups, planned contrasts to investigate the priming effects for studied and unstudied words were conducted in each group. They showed significant priming effects in the predicted direction only for false alarms in the visual group ($t(1,16) = 3.04$, $p = .008$), but not in the auditory group on either studied or unstudied words.

A 3 x 2 x 2 (group by priming by study status) on proportions of K responses showed a significant 3-way interaction study status x priming x group ($F(1,33) = 4.48$, $p = .042$, partial $\eta^2 = .119$), a significant main effect of study status (simply showing that participants made more K responses to studied items than to unstudied ones), but no significant main effects of priming ($F(1, 33) = 3.42$, $p = .073$, partial $\eta^2 = .094$) or of group ($F(1,33) = .17$, $p = .686$, partial $\eta^2 = .005$). The following interactions were not significant: study status x group ($F(1,33) = .04$, $p = .851$, partial $\eta^2 = .001$; priming x group ($F(1,33) = .41$, $p = .526$), study status x priming ($F(1,33) = .28$, $p = .597$, partial $\eta^2 = .009$). In order to explore the 3-way interaction, paired-samples t-tests were conducted in each group, separately for studied and unstudied words. The only significant priming effect was on K false alarms in the visual study group ($t(1,16) = 2.76$, $p = .014$). There were no significant priming effects on the proportions of R responses in either group.

Appendix 3 – Supplementary materials for Chapter 4

Appendix 3.1. Histogram of recollection false alarms in Experiment 1



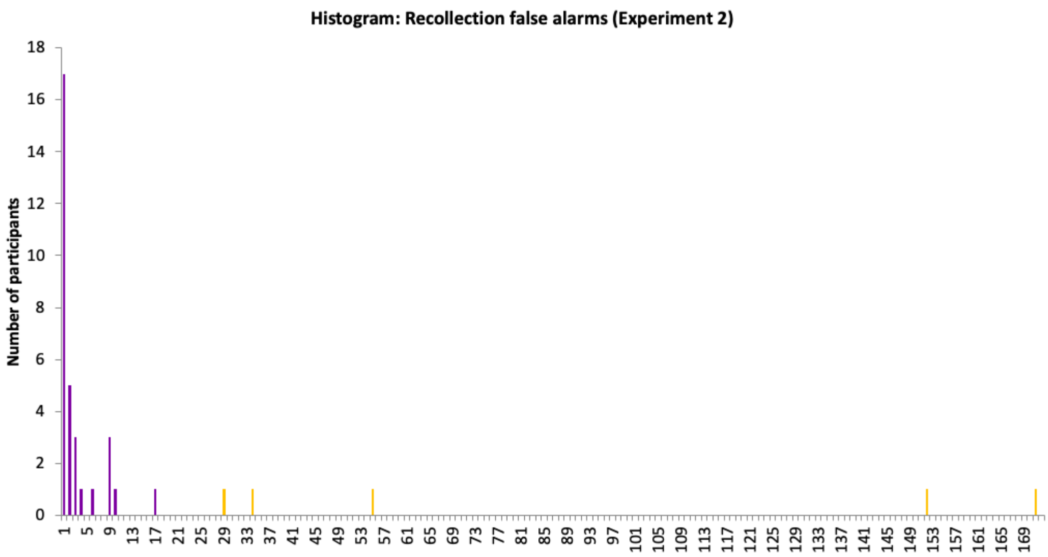
Appendix 3.2. Targets and their context and prime words used in Experiment 1

List no	Target	Context 1	Prime 1	Context 2	Prime 2	Unrelated prime
LIST 1	COOKIE	dough	oven	biscuit	snack	elderly
LIST 1	WRINKLES	senior	elderly	fabric	smooth	vision
LIST 1	RUM	sailor	pirate	drink	cocktail	indicate
LIST 1	LENS	camera	photo	glasses	vision	cocktail
LIST 1	ARROW	sharp	quiver	direction	indicate	oven
LIST 2	BARK	puppy	growl	angry	shout	tummy
LIST 2	GUTS	stomach	tummy	courage	bravery	student
LIST 2	ANGEL	caring	tender	divine	spiritual	routine
LIST 2	GRADE	hierarchy	rank	exam	student	tender
LIST 2	CUSTOM	culture	heritage	habit	routine	growl
LIST 3	LAB	computer	software	chemical	substance	tooth
LIST 3	BOIL	heat	simmer	temper	rage	button
LIST 3	HONEY	bee	flower	dear	darling	simmer
LIST 3	CROWN	monarchy	royal	enamel	tooth	darling
LIST 3	PAUSE	discourse	hesitate	recorder	button	software
LIST 4	ARTIST	designer	graphic	composer	opera	grief
LIST 4	PAINTING	plaster	wall	portrait	museum	model
LIST 4	TEARS	emotion	grief	onion	chopping	premiere
LIST 4	OPENING	cavity	hole	launch	premiere	graphic
LIST 4	TRAIN	express	railway	toy	model	wall
LIST 5	TEAM	soccer	league	bunch	gang	box
LIST 5	BROWN	chocolate	cocoa	tan	skin	opinion
LIST 5	FREEDOM	jail	prison	viewpoint	opinion	league
LIST 5	MATERIAL	data	facts	quality	suitable	cocoa
LIST 5	PIZZA	Italian	pasta	delivery	box	suitable
LIST 6	MIRAGE	fantasy	dream	desert	oasis	wave
LIST 6	APEX	mountain	peak	career	success	change
LIST 6	SURF	tide	wave	Internet	website	fly
LIST 6	COIN	flip	luck	penny	change	peak
LIST 6	SAIL	cruise	ship	swoop	fly	dream
LIST 7	SKELETON	plan	outline	bones	anatomy	fowl
LIST 7	TIGER	zoo	cage	ambitious	fierce	wreck
LIST 7	VERSE	poetry	rhyme	scripture	bible	outline
LIST 7	RUIN	Roman	ancient	damage	wreck	cage
LIST 7	TURKEY	roast	stuffing	poultry	fowl	bible
LIST 8	STROKE	punch	hit	blood	cerebral	formal
LIST 8	PAYMENT	receipt	purchase	salary	wage	sign
LIST 8	BURN	acid	rash	consume	calorie	purchase

LIST 8	SUIT	swimming	pool	tailor	formal	rash
LIST 8	MEANING	value	worth	symbol	sign	hit
LIST 9	VISIT	official	ceremony	exhibit	gallery	mirror
LIST 9	LETTER	character	alphabet	envelope	post	pink
LIST 9	GLASS	beer	pint	reflect	mirror	ceremony
LIST 9	PEACH	juicy	fruit	colour	pink	porcelain
LIST 9	TILE	roof	clay	bathroom	porcelain	alphabet
LIST 10	ROBBERY	burglary	theft	overprice	expensive	tag
LIST 10	BADGE	surname	tag	insignia	emblem	theft
LIST 10	LIMB	arm	leg	bough	branch	jacuzzi
LIST 10	TUB	container	lid	hot	jacuzzi	explorer
LIST 10	GLOBE	atlas	map	journey	explorer	leg
LIST 11	THUNDER	storm	crash	vocal	tone	wish
LIST 11	BRONZE	medal	contest	bell	copper	crash
LIST 11	PRAYER	ritual	kneel	request	wish	princess
LIST 11	ROOT	loam	plant	ancestor	origin	contest
LIST 11	CASTLE	medieval	fortress	legend	princess	origin
LIST 12	OCEAN	whale	shark	abundance	plenty	escalate
LIST 12	PARTNER	couple	husband	associate	investor	deed
LIST 12	SWING	outdoor	slide	mood	shift	shark
LIST 12	CLIMB	ascend	mount	price	escalate	husband
LIST 12	MEASURE	ruler	meter	step	deed	slide
LIST 13	TRAFFIC	highway	queue	trading	dealing	pawn
LIST 13	EQUAL	unbiased	impartial	analogous	alike	shopping
LIST 13	MORAL	code	ethic	message	lesson	queue
LIST 13	PIECE	portion	sample	chess	pawn	impartial
LIST 13	MARKET	economy	demand	grocery	shopping	lesson
LIST 14	ITCH	mosquito	tingling	craving	urge	lamp
LIST 14	BULB	lighting	lamp	tuber	potato	keys
LIST 14	CONCH	marine	snail	piercing	ear	trophy
LIST 14	LOCK	river	canal	gate	keys	tingling
LIST 14	CUP	coffee	tea	gold	trophy	snail
LIST 15	DOG	policeman	search	guide	blind	fence
LIST 15	SPEED	penalty	fine	physics	motion	search
LIST 15	BITE	cobra	venom	eat	chew	prince
LIST 15	BARRIER	language	cultural	barricade	fence	chew
LIST 15	FROG	lizard	pond	kiss	prince	fine
LIST 16	STRESS	strain	anxiety	syllable	emphasis	lantern
LIST 16	HORN	whistle	siren	reindeer	elk	grace
LIST 16	STYLE	elegance	grace	method	approach	pass
LIST 16	PUMPKIN	cucumber	squash	carved	lantern	siren
LIST 16	TICKET	officer	warning	permit	pass	anxiety
LIST 17	OVAL	shape	circle	president	desk	drama
LIST 17	SWALLOW	intake	throat	tolerate	endure	shelf
LIST 17	STORAGE	rack	shelf	digital	disc	throat
LIST 17	COMEDY	horror	drama	laughter	joy	azure

LIST 17	BLUE	horizon	azure	depressed	sad	circle
LIST 18	COLUMN	editorial	magazine	pillar	arch	trauma
LIST 18	BRAIN	intellect	genius	neuron	cortex	poker
LIST 18	KING	cards	poker	dynasty	empire	magazine
LIST 18	HOSPITAL	maternity	newborn	emergency	trauma	galaxy
LIST 18	SPACE	extent	capacity	planet	galaxy	genius

Appendix 3.3. Histogram of recollection false alarms in Experiment 2



Appendix 3.4. Targets and their context and prime words used in Experiment 2

Same meaning primes

Target	Context word	Prime
BAND	musicians	concert
SHED	shelter	hut
STEM	plant	branch
ORGAN	choir	keyboard
PITCH	football	stadium
POST	pillar	pole
NET	fishing	catch
PALM	tropical	coconut
BILL	beak	snout
SOLE	lone	solo
FILE	papers	directory
MOLE	spot	blemish
ADDRESS	residence	stamp
BOIL	steam	vapour
LAP	limb	knee
HORN	bull	antler
JAM	traffic	stuck
GRAND	currency	cash
BOLT	flash	thunder
GROOM	appearance	comb
WAKE	nap	dream
CALF	cow	puppy
BLOW	exhale	storm
CAVE	hollow	cliff
POOL	liquid	puddle
STICK	cane	twig
BARK	tree	trunk
SPRING	jump	bounce
SINK	descend	drown
GILL	unit	pint

Different meaning primes

Target	Context word	Prime
NAIL	finger	spanner
RASH	itch	careful
FIT	healthy	tailor

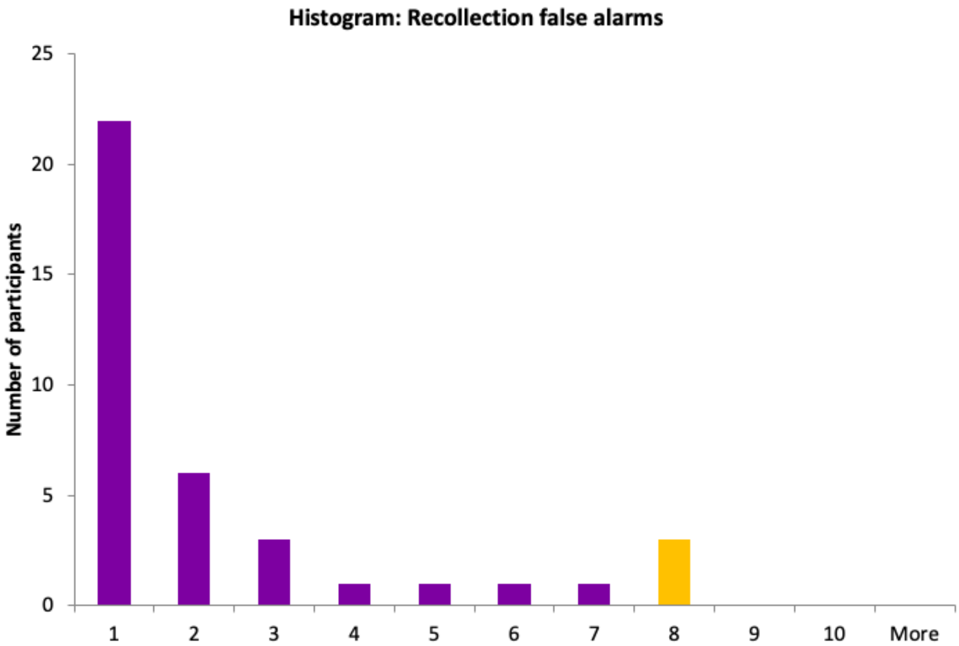
HATCH	egg	trapdoor
BORE	tunnel	yawn
IRON	fabric	rod
DATE	calendar	lover
FIRM	corporate	solid
CAMP	gesture	refugee
PARK	store	bench
CABINET	cupboard	board
ROW	tier	paddle
BUG	insect	annoy
WAVE	greeting	shore
OBJECT	item	disagree
CUE	ball	prompt
SEASON	flavour	era
TRIP	slip	cruise
CURRENT	electric	ongoing
JOINT	collective	muscle
CAST	molten	toss
CLOG	block	wooden
TEAR	hole	sadness
REAR	backside	parent
DUCK	feather	crouch
YARD	length	balcony
BEAR	carry	howl
CHECK	pattern	inspect
TIE	shirt	join
SEAL	secure	mammal

Unrelated primes

Target	**Context word**	**Prime**
CLUB	league	keyboard
FLAG	banner	roar
STALL	booth	dirt
SOIL	clay	travel
TANK	container	jail
PEER	scan	inspect
ROSE	rise	male
EXPRESS	speed	youth
TOLL	bell	balcony
MATCH	lighter	cocoon
TANGO	latin	concert
CORN	grain	column
SCALE	device	damage
GRAVE	tomb	applause
FAIR	carnival	branch
MARCH	june	fin

CHIP	potato	coffee
BEAM	ray	vessel
LOCK	tress	minute
GUM	chew	leaves
PATIENT	medical	witch
CRAFT	skill	cliff
CELL	prison	hut
BRIDGE	crossing	mould
PUPIL	teacher	samba
SPIKE	poison	symbol
COUNT	aristocrat	goose
SPELL	letters	polish
BASE	alkali	mammal
CROSS	crucify	student

Appendix 3.5. Histogram of recollection false alarms in Experiment 3



Appendix 3.6. Targets and their context and prime words used in Experiment 3

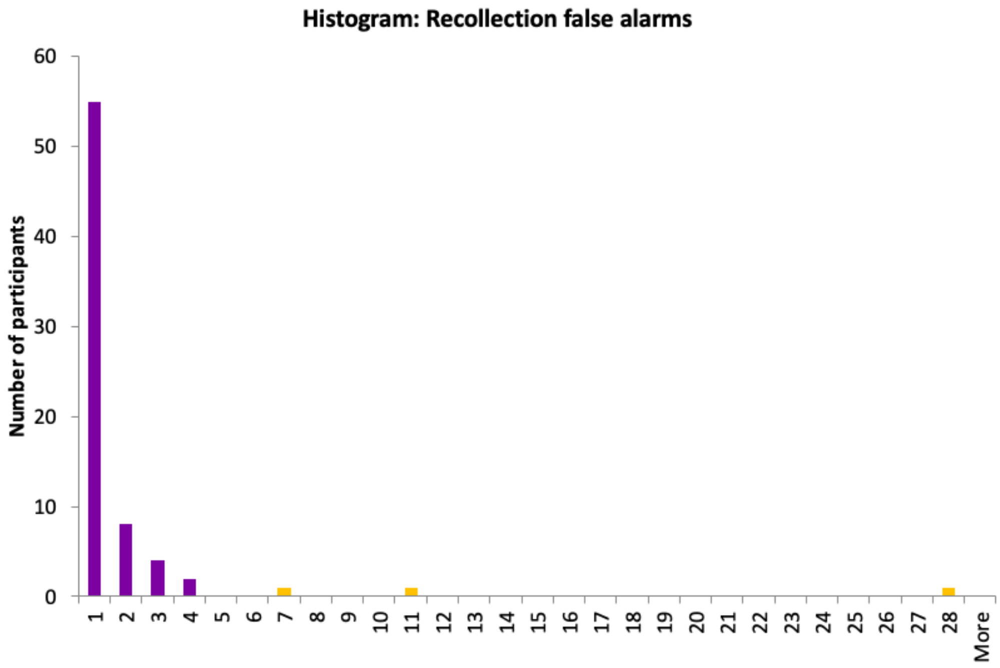
LIST	**Target**	**Context 1**	**Prime 1**	**Context 2**	**Prime 2**	**Unrelated prime**
LIST 1	HOP	rabbit	bounce	ale	brewery	repulsive
LIST 1	RANK	foul	repulsive	hierarchy	classify	shake
LIST 1	HATCH	chick	shells	opening	escape	bounce
LIST 1	GOBBLE	greed	gorge	turkey	noise	shells
LIST 1	ROCK	sway	shake	pebble	smash	gorge
LIST 2	PORT	wine	bottle	docks	anchor	protest
LIST 2	PEN	enclosure	cage	pencils	doodle	endure
LIST 2	FRY	oil	chips	offspring	larvae	anchor
LIST 2	BEAR	growled	mammal	tolerate	endure	larvae
LIST 2	RAIL	track	route	rebel	protest	doodle
LIST 3	CRICKET	insect	song	catcher	batter	sheet
LIST 3	CORN	varuca	plaster	maize	yellow	song
LIST 3	STABLE	horse	hay	balanced	steady	plaster
LIST 3	SCRAP	rusty	dumpster	quarrel	argue	hay
LIST 3	PAGE	leaflet	sheet	doctor	summon	dumpster
LIST 4	LEAN	slant	angle	skinny	slender	digging
LIST 4	MOLE	spot	blot	burrow	digging	artery
LIST 4	PULSE	lentils	beans	monitor	artery	browser
LIST 4	BARK	tree	trunk	howl	snarl	slender
LIST 4	COOKIE	crumbs	biscuit	internet	browser	snarl
LIST 5	STRIP	naked	bare	section	segment	calendar
LIST 5	GRAVE	deceased	coffin	serious	gloomy	throat
LIST 5	POST	mail	stamp	pillar	pole	coffin
LIST 5	MARCH	April	calendar	soldiers	walking	bare
LIST 5	HUSKY	raspy	throat	breed	pet	stamp
LIST 6	LIMP	floppy	loose	crutches	cane	draw
LIST 6	PLANE	surface	uniform	flights	cabin	document
LIST 6	FILE	nails	smooth	folder	document	cabin
LIST 6	BORE	tiring	snore	drilled	screw	cane
LIST 6	PAD	patter	tread	sketch	draw	screw
LIST 7	LIE	deceived	false/	lounge	relax	flower
LIST 7	BILL	beak	snout	waitress	cheque	bread
LIST 7	STEM	plant	flower	restrict	limit	bracelet
LIST 7	BAND	elastic	bracelet	concert	guitar	snout
LIST 7	JAM	marmalade	bread	traffic	delay	false/
LIST 8	CAPE	mantle	cloak	coast	peninsula	iceberg
LIST 8	MAROON	abandon	forget	purple	brownish	payment
LIST 8	SINK	towel	wash	Titanic	iceberg	tossed
LIST 8	PITCHER	jug	container	baseball	tossed	brownish

LIST 8	TOLL	loud	peal	charge	payment	peninsula
LIST 9	LIMBO	uncertain	confused	dancing	bending	bet
LIST 9	HOST	crowd	assembly	guest	welcome	forest
LIST 9	STAKE	odds	bet	fence	prop	assembly
LIST 9	BOIL	pus	pores	kettle	heating	confused
LIST 9	ASH	leaf	forest	cinders	burnt	pores
LIST 10	FAN	supporter	celebrity	cool	aerator	reproduce
LIST 10	SEAL	glue	fasten	zoo	marine	aerator
LIST 10	JUMPER	sweater	wool	hurdle	athlete	marine
LIST 10	HIDE	leather	cows	secret	invisible	athlete
LIST 10	STUD	piercing	ear	breeding	reproduce	invisible
LIST 11	PEEP	spy	sneak	squeak	whimper	glory
LIST 11	PITCH	tempo	melody	stadium	turf	tremble
LIST 11	SHIVER	freezing	tremble	vase	splinter	melody
LIST 11	RACE	winning	glory	identity	equality	itch
LIST 11	RASH	eczema	itch	impulsive	reckless	sneak
LIST 12	BAT	games	strike	cave	nocturnal	crops
LIST 12	PLOT	twists	surprise	alottment	crops	dawn
LIST 12	LIGHTEN	cheer	lift	brighten	dawn	whisper
LIST 12	UTTER	complete	absolute	pronounce	whisper	packet
LIST 12	GUM	enamel	dentist	bubble	packet	nocturnal
LIST 13	FAIR	justice	moral	park	rides	blast
LIST 13	TENSE	worry	anxious	speech	languages	fake
LIST 13	SAGE	guru	wisdom	garnish	recipe	anxious
LIST 13	FORGE	signature	fake	armour	knight	wisdom
LIST 13	BOOM	explosion	blast	inflation	prices	moral
LIST 14	VAULT	locked	valuable	olympics	obstacle	prince
LIST 14	KEYS	security	shut	islands	coral	team
LIST 14	LEAGUE	mile	length	contest	team	coral
LIST 14	MOULD	fungus	bacteria	pottery	clay	obstacle
LIST 14	BALL	tennis	racket	reception	prince	clay
LIST 15	SPADE	heart	diamond	shovel	tools	platform
LIST 15	REAR	hind	bottom	educate	raise	calculate
LIST 15	BRIDGE	arch	platform	cards	players	debts
LIST 15	BUST	bankrupt	debts	sculpture	statue	diamond
LIST 15	COUNT	numerical	calculate	nobility	title	bottom
LIST 16	TENDER	loving	caring	formal	submit	highest
LIST 16	TAP	drum	rap	basin	liquid	submit
LIST 16	CALF	farm	lamb	muscle	cramp	liquid
LIST 16	MOUNT	ride	saddle	altitude	highest	publish
LIST 16	NOVEL	original	fresh	author	publish	cramp
LIST 17	HAMPER	sabbotage	hinder	basket	picnic	flirt
LIST 17	ROCKET	greens	salad	spaceship	astronaut	damaged
LIST 17	CHAP	fella	guy	lips	dry	salad
LIST 17	DATE	romance	flirt	fig	dried	hinder
LIST 17	SOIL	stain	damaged	compost	worm	guy

LIST 18	FUSE	socket	switch	combine	blend	smell
LIST 18	PUPIL	vision	iris	scholar	exams	legal
LIST 18	FIRM	confident	decisive	corporate	legal	verse
LIST 18	REFRAIN	withhold	abstain	chorus	verse	blend
LIST 18	ROSE	rebirth	awaken	garden	smell	exams
LIST 19	SETTLE	seat	bench	stability	retire	trim
LIST 19	MATE	chess	victory	pal	companion	victory
LIST 19	PAWN	puppet	powerless	auction	sell	bench
LIST 19	CLIP	scissors	trim	accessory	pin	ice
LIST 19	HAIL	weather	ice	celebrate	admire	powerless
LIST 20	GRATE	drain	pavement	cheese	pizza	blonde
LIST 20	SEWER	pipes	waste	stitch	needle	pizza
LIST 20	JET	aircraft	airport	colour	shade	snack
LIST 20	LOCK	latch	safe	curl	blonde	shade
LIST 20	PRUNE	bushes	shears	plum	snack	needle
LIST 21	SOLE	singular	solitary	boot	beneath	canoe
LIST 21	LAP	circuit	loop	knee	thigh	coal
LIST 21	POKER	prod	coal	gamble	wager	covering
LIST 21	SCALE	lizard	covering	bathroom	weight	loop
LIST 21	ROW	paddle	canoe	column	sequence	solitary
LIST 22	PUMP	balloon	tyre	slipper	heel	roll
LIST 22	CHECK	tick	ascertain	stripes	squares	happiness
LIST 22	BOWL	plate	spoon	throw	roll	heel
LIST 22	POOL	swim	lake	billiards	pub	squares
LIST 22	EXPRESS	postage	urgent	emotion	happiness	pub
LIST 23	CUFF	punish	slap	sleeve	shirt	squat
LIST 23	PINE	yearn	moan	conifer	Christmas	slap
LIST 23	DUCK	dodge	squat	pond	bird	moan
LIST 23	TEMPLE	brow	skull	mosque	sacred	flavour
LIST 23	MINT	mojito	flavour	amazing	excellent	skull
LIST 24	CUE	hint	prompt	snooker	hit	laugh
LIST 24	TAG	touch	chase	label	sticker	gaze
LIST 24	PALM	Hawaii	coconut	finger	knuckles	sticker
LIST 24	PEER	colleague	fellow	glance	gaze	knuckles
LIST 24	GAG	reflex	vomit	comedy	laugh	hit
LIST 25	SPELL	charm	witch	alphabet	letters	obey
LIST 25	POUND	dollar	euro	thump	bash	follow
LIST 25	MINE	pit	extract	ownership	self	euro
LIST 25	STALK	prey	follow	vegetable	root	witch
LIST 25	STICK	abide	obey	branch	wood	extract
LIST 26	VICE	weakness	guilt	clamp	engineer	infant
LIST 26	EGG	breakfast	toast	provoke	influence	wand
LIST 26	LOAF	sofa	lazy	crusty	bakery	influence
LIST 26	KID	bluff	mislead	youth	infant	engineer
LIST 26	CAST	credits	movie	cursed	wand	bakery
LIST 27	TILL	plough	turning	cashier	purchase	partner

LIST 27	CAMP	glamorous	feminine	tents	hiking	raw
LIST 27	RING	marriage	partner	dial	contact	turning
LIST 27	RARE	succulent	raw	uncommon	limited	squeeze
LIST 27	SQUASH	flatten	squeeze	pumpkin	seeds	feminine
LIST 28	MULE	donkey	pony	sandal	shoe	beauty
LIST 28	STUNT	impress	trick	impede	prevent	lungs
LIST 28	BLOW	fist	dizzy	puff	lungs	securing
LIST 28	STRAPPING	muscular	fit	binding	securing	shoe
LIST 28	LINER	cruise	dock	lipstick	beauty	prevent
LIST 29	RAY	blinds	sunny	shark	ocean	polish
LIST 29	YARD	lawn	tarmac	distance	measure	candle
LIST 29	MATCH	flame	candle	sport	coach	discard
LIST 29	SHED	skin	discard	barn	shack	sunny
LIST 29	GLOSS	varnish	polish	index	meaning	tarmac
LIST 30	STAPLE	attach	metal	essential	principal	scent
LIST 30	ELDER	relative	bigger	blossom	scent	sum
LIST 30	NET	mesh	web	finance	sum	spice
LIST 30	KITTY	funds	petty	cat	whiskers	principal
LIST 30	BAY	beach	tide	herbs	spice	whiskers

Appendix 3.7. Histogram of recollection false alarms in Experiment 4 across groups



Appendix 3.8. Additional analyses

Experiment 1

Supplementary Table 1 | Mean proportions of K responses in Experiment 1 (with standard deviations in brackets) to Studied words only for each Priming condition (Same context primes/Different context primes/Unrelated primes).

Response	Studied words (stimuli of interest only)		
	Same context prime	Different context prime	Unrelated prime
K	0.25 (0.13)	0.22 (0.12)	0.23 (0.13)

The main ANOVA (i.e., all participants, all trials) on K Hits did not yield a significant effect ($F(2,60) = 1.02$, $p = .368$, partial $\eta^2 = .033$). When analysing only "correctly" encoded trials, the ANOVA on K Hits did not show a significant main effect of priming ($F(2,60) = 1.25$, $p = .293$, partial $\eta^2 = .040$). When analysing a subsample of participants who could not read the primes, there was no significant main effect of priming on the proportions of K Hits ($F(2,40) = 2.84$, $p = .070$, partial $\eta^2 = .124$). However, because there was a non-significant trend of priming and this has been investigated with paired-samples t-tests to compare the 3 priming conditions. Of the 3 comparisons, with a Bonferroni-corrected significance level of .017, there was a nearly significant difference between the same context and different context priming conditions ($t(1,20) = 2.24$, $p = .037$), with a higher proportion of K hits for words preceded by same context primes compared to words preceded by difference context primes.

Supplementary Table 2 | Proportions of R and iK responses for trials participants found related in the encoding in Experiment 1 (SD in parantheses)

Response	Studied words (target words of interest only, "correctly encoded" trials only)		
	Same context prime	Different context prime	Unrelated prime
R	0.53 (0.19)	0.55 (0.19)	0.52 (0.22)
iK	0.46 (0.19)	0.42 (0.19)	0.46 (0.23)
New	0.25 (0.12)	0.26 (0.13)	0.27 (0.17)

Supplementary Table 3 | Proportions of K responses for trials participants found related in the encoding in Experiment 1 (SD in parantheses)

Response	Studied words (target words of interest only, "correctly encoded" trials only)		
	Same context prime	Different context prime	Unrelated prime
K	0.22 (0.13)	0.20 (0.11)	0.21 (0.13)

Experiment 2

Supplementary Table 4 | Mean proportions of K responses in Experiment 2 (with standard deviations in brackets) to Studied words only for each Priming condition (Same meaning primes/Different meaning primes/Unrelated primes).

Response	Studied words (homonyms only)		
	Same meaning primes	Different meaning primes	Unrelated primes
K	0.19 (0.12)	0.22 (0.12)	0.22 (0.11)

The main repeated-measures ANOVA with priming as factor on K Hits did not yield a significant effect ($F(2,62) = 1.812$, $p = .172$, partial $\eta^2 = .055$). When analysing only "correctly" encoded trials, the ANOVA on K Hits ($F(2,62) = 1.03$, $p = .364$, partial $\eta^2 = .032$) did not show any significant priming effects.

Supplementary Table 5 | Proportions of R and iK responses for trials participants found related in the encoding in Experiment 2 (SD in parantheses)

Response	Studied words (homonyms only, "correctly encoded" trials only)		
	Same meaning primes	Different meaning primes	Unrelated primes
R	0.55 (0.23)	0.49 (0.23)	0.52 (0.24)
iK	0.39 (0.25)	0.38 (0.21)	0.42 (0.19)

Supplementary Table 6 | Proportions of K responses for trials participants found related in the encoding in Experiment 2 (SD in parantheses)

Response	Studied words (homonyms only, "correctly encoded" trials only)		
	Same meaning primes	Different meaning primes	Unrelated primes
K	0.17 (0.14)	0.19 (0.13)	0.19 (0.12)

With a subsample of participants (*N* = 28), there was a significant effect of priming of the proportions of R Hits (F(2,54) = 4.62, *p* = .014 partial η^2 = .146). Post-hoc t-tests showed significantly more R Hits in the same meaning condition compared to the different meaning condition (t(1,27) = 2.547, *p* = .017) and a nearly significant difference between the same meaning and unrelated conditions (t(1,27) = 2.185, *p* = .038), given a Bonferroni-corrected threshold of .017. The priming effect was not significant on familiarity hits (K Hits: F(2,54) = 1.42, *p* = .250, partial η^2 = .050; iK Hits: F(2,54) = 1.74, *p* = .185, partial η^2 = .061).

Experiment 3

Supplementary Table 7 | Proportions of K responses in Experiment 3 (SD in parantheses)

Response	Studied words (homonyms only)		
	Same meaning primes	Different meaning primes	Unrelated primes
K	0.22 (0.12)	0.27 (0.14)	0.24 (0.14)

The repeated-measures ANOVA with priming as factor on K Hits showed a significant effect of priming (F(2,68) = 4.40, *p* = .016, partial η^2 = .114). Post-hoc paired-samples t-tests showed significant differences between the same meaning priming and different meaning priming conditions (t(1,34) = 3.507, *p* = .001) with higher proportions of K responses in the different meaning condition compared to the same meaning condition. There were no significant differences between the same meaning and the unrelated priming conditions (t(1,34) = 1.115, *p* = .273) or between the different meaning and unrelated priming conditions (t(1,34) = 1.574, *p* = .125).

Supplementary Table 8 | Proportions of K responses in each priming condition in Experiment 3, after the post-hoc coding of dominant/subordinate meanings of target homonyms (SD in parantheses)

	Studied words (homonyms only)					
	Dominant encoding meaning			Subordinate encoding meaning		
	Same meaning prime (dominant)	Different meaning prime (subordinate)	Unrelated prime	Same meaning prime (subordinate)	Different meaning prime (dominant)	Unrelated prime
K	0.22 (0.13)	0.26 (0.16)	0.24 (0.16)	0.23 (0.15)	0.27 (0.15)	0.25 (0.16)

The analysis on K responses when including encoded meaning dominance as factor only yielded a significant main effect of priming ($F(2,68) = 3.26$, $p = .045$, partial $\eta^2 = .087$), but not a significant effect of encoded meaning dominance ($F(1,34) = .64$, $p = .428$, partial $\eta^2 = .019$) and no significant interaction between the two factors ($F(2,66) = .01$, $p = .996$, partial $\eta^2 < .001$). As for R responses, separate tests were performed to compare the priming conditions separately for dominant encoded meanings and subordinate encoded meanings. For target words encoded with their dominant meaning, there were no significant differences between same meaning and unrelated priming conditions ($p = .226$, uncorrected, one-tailed) or between different meaning and unrelated priming conditions ($p = .190$, uncorrected, one-tailed), but there was a significant difference between the same meaning and the different meaning priming conditions ($p = .043$, uncorrected, one-tailed). Similarly, for target words encoded with their subordinate meaning, there were no significant differences between the same meaning and the unrelated priming conditions ($p = .273$, uncorrected, one-tailed) or between the different meaning and the unrelated priming conditions ($p = .139$), but there was a significant difference between the same meaning and the different meaning priming conditions ($p = .028$, uncorrected, one-tailed). For both words encoded with the dominant meaning and words encoded with their subordinate meaning, there was a higher proportion of K responses when they were preceded by different meaning primes than when they were preceded by same meaning primes. In other words, regardless of the meaning dominance of the encoding context, different meaning primes increased familiarity compared to same meaning primes.

<u>Statistical analyses after excluding the encoding trials participants in Experiment 3 did not find related</u>

There was a main effect of priming on K responses ($F(2,68) = 5.73$, $p = .005$, partial $\eta^2 = .144$), post-hoc tests showing significantly higher proportions of K responses for words preceded by different meaning primes compared to words preceded by same meaning primes (t(1,34) = 4.241, p < .001, Bonferroni-corrected significance level = .017), a nearly significant difference between different meaning and unrelated priming conditions (t(1,34) = 1.898, p = .066) and no significant difference between the same meaning and unrelated priming conditions (t(1,34) = 1.066, p = .294).

Experiment 4

Supplementary Table 9 | Proportions of K responses in Experiment 4 (SD in parantheses)

Response	Studied words (homonyms only)			
	Same meaning group		Different meaning group	
	Primed	Unprimed	Primed	Unprimed
K	0.32 (0.12)	0.29 (0.12)	0.27 (0.13)	0.27 (0.14)

The main ANOVA on K responses did not show any significant main effects of priming (F(1,67) = 1.33, p = .253, partial η^2 = .019), of group (F(1,67) = 1.63, p = .206, partial η^2 = .024) and no significant interaction between the two factors (F(1,67) = 1.58, p = .213, partial η^2 = .023).

When including encoding meaning dominance as a factor in the ANOVA. The 2x2x2 ANOVA on K responses yielded a significant interaction between Encoding meaning dominance * Priming (F(1,67) = 7.93, p = .006, partial η^2 = .106), with post-hoc tests showing a priming effect on K responses to target words presented in subordinate encoding contexts (t(1,68) = 3.160, p = .002, Bonferroni-corrected threshold = .025), but not in dominant encoding contexts (t(1,68) = 1.316, p = .193). The same ANOVA also showed a significant main effect of Encoding meaning dominance (F(1,67) = 12.50, p = .001, partial η^2 = .157), with significantly more K responses for target words presented in subordinate encoding contexts than for words presented in dominant encoding contexts. However, when the analysis on proportions of familiarity responses was calculated under independence assumptions (iK = K/(1-R); Yonelinas & Jacoby, 1995), the main effect of Encoding meaning dominance disappeared (see full results on iK in the Supplementary Materials). The rest of the effects were not significant: main effect of priming (F(1,67) = 1.36, p = .248, partial η^2 = .020; main effect of group (F(1,67) = 1.63, p = .206, partial η^2 = .024), interaction Encoding meaning dominance*Group (F(1,67) = .63, p = .431, partial η^2 = .009); interaction Priming*Group (F(1,67) = 1.65, p = .203, partial

η^2 = .024); interaction Encoding meaning dominance*Priming*Group ($F(1,66)$ = .04, p = .840, partial η^2 = .001). Planned contrasts were performed to compare the proportions of K responses in primed versus unprimed conditions in each group, separately for the words encoded with dominant meanings and subordinate meanings. There were no significant priming effects on R responses in either group. When looking at the proportions of K responses, the planned contrasts showed a nearly significant priming effect in the Same meaning group only, for words encoded with the subordinate meaning ($t(1,33)$ = 2.599, p = .014, Bonferroni-corrected threshold = .0125).

<u>Statistical analyses after excluding encoding trials participants did not find related in Experiment 4</u>

The 2 x 2 ANOVA on R responses showed a significant main effect of group ($F(1,67)$ = 4.19, p = .045, partial η^2 = .059), with a higher proportion of R responses in the Different meaning group compared to the Same meaning group. It did not show a significant main effects of priming ($F(1,67)$ = .07, p = .791, partial η^2 = .001) or a significant interaction between the two factors ($F(1,67)$ = .09, p = .767, partial η^2 = .001). The 2 x 2 ANOVA on K responses did not show any significant main effects of priming ($F(1,67)$ = 1.26, p = .265, partial η^2 = .018), of group ($F(1,67)$ = 2.10, p = .152, partial η^2 = .030) and no significant interaction between the two factors ($F(1,67)$ = .42, p = .522, partial η^2 = .006). The 2 x 2 ANOVA on iK responses did not show any significant main effects of priming ($F(1,67)$ = 2.26, p = .138, partial η^2 = .033), of group ($F(1,67)$ = .32, p = .571, partial η^2 = .005) and no significant interaction between the two factors ($F(1,67)$ = .47, p = .496, partial η^2 = .007).