The Role of Working Memory in Spontaneous Recognition: Neural Correlates and Behavioural Influences in the Memory Stroop Paradigm

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Abstract

Research suggests that unintentional recognition of distracting non-target stimuli can bias goal-related, intentional recognition judgements to target stimuli encountered in the same environment. Spontaneous recognition (SR) effect can be defined as the unintentional recognition of stimuli and is measured by the effect of familiarity to distractors on a recognition task. This thesis investigated how previously seen or not-seen distractors affect recognition of targets when working memory (WM) resources are manipulated by a secondary WM load task (chapter 2), using both behavioural and ERP measures (Chapter 3). The findings suggest that when working memory resources are low, SR is then easier to observe. Additionally, neural and memory processes are dissociable for unintentional and intentional recognition and retrieval monitoring is found to be enhanced when the new targets were paired with old distractors. Furthermore, the findings on the early ERPs may suggest that the proactive control might be activated. Finally, a set of experiments revealed that, SR effect may not be related to conscious awareness since having a low or high confidence did not modulate the SR effect indicating a lack of conscious awareness of the SR effect (Chapter 4). Together these findings may help to understand the mechanisms underlying the SR effect.

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Chapter 1: Introduction

1. Main concepts

1.1. Overview

The experiments presented in this thesis explored how unintentional recognition of the distractors affect intentional recognition memory which can be termed as the ‘spontaneous recognition effect’. Specifically, I looked at the behavioural effects and neural correlates of spontaneous recognition. To do so I used the memory Stroop paradigm and manipulated a number of cognitive constructs such as working memory and emotion and investigated the role of subjective confidence judgements.

In this Chapter, I will start by giving an overview on intentional and unintentional memory, reviewing theories of recognition memory and the theoretical background as well as studies on working memory. I will discuss the several interpretations of recognition memory. Following this, I will present an overview of studies of SR effect. Second part of the chapter is concerned with familiarising the reader with the tasks and methodology used in this thesis which included, reviewing colour-word Stroop task and its mechanisms, introducing the memory Stroop task which will be used to investigate SR effect and explaining the rationale of using n-back task as a WM manipulation. Additionally, this chapter reviews the recognition confidence measurements before introducing the experiments in this thesis.

1.2. Intentional and Unintentional Memory

Research on the function of memory recognises “intentional” and “unintentional” memory as its two main constituents (Berntsen, 1996; Mace, 2008; Mandler, 2008; Watson, Berntsen, Kuyken, & Watkins, 2013). Intentional memory is activated when individuals engage in deliberate effort to recall an event (e.g. previous experiences).

This aspect of memory has been widely investigated in both theoretical and experimental studies, owing to an ease of testing its functions methodologically. Intentional memories are relatively easy to work on because the concept of it allows researchers to question memories directly and/or to measure it using a variety of paradigms.

On the other hand, unintentional memory is considered automatic and usually occurs with lack of intent which is considered to be the new interest in cognitive neuroscience (Hall et al., 2014). As such, the difference between intentional and unintentional memory is clear, insofar as intentional memories require intention and effort towards recall whereas unintentional memories are stimulus-driven (Anderson, Jacoby, Thomas, & Balota, 2011).

Preliminary research on the workings of intentional memory date back to the 1970s whilst unintentional memory remained unspecified until the late 1990s. One of the first studies on unintentional memories was conducted by Berntsen in 1996. The researcher described unintentional autobiographic memories as memories of past events that occur spontaneously without any attempts for intentional retrieval (Berntsen, 1996). In turn, she suggested, that our daily lives are governed by equal amounts of unintentional and intentional memories, despite their underlying functional differences (Berntsen, 1996). However, Rasmussen, Ramsgaard and Berntsen (2015) asked participants to record their intentional and unintentional memories with a mechanical counter and found a three-to-one frequency correspondence in unintentional memories, as compared to intentional ones. Additionally, a study using retrospective methods to measure the occurrence of unintentional memories indicated the latter were more frequent in healthy individuals

(Brewin, 1996). These studies suggest that past experiences which come to mind unintentionally are more frequent and common than originally suggested.

Despite increased research into unintentional memories, findings on their content and underlying processing mechanisms relative to intentional memories, remain unclear. For instance, Mace (2008) distinguishes between three types of unintentional memories, namely: ones that occur during cognitive processing, ones that occur during autobiographical recall and ones that are associated with specific psychological disorders. Elsewhere, Mandler (2008) argues that there are three major variants of unintentional memories. Firstly, brief unintentional (semantic) memories which are brief unintentional memories that occur spontaneously even with a lack of overt cues and that are generally the by-product of relatively automatic activities. Secondly for unintentional autobiographical memories, which occur without any intention to recall, and are connected to past life events. The third and last variant of unintentional memory is relevant to dreams (Mandler, 2008). Unintentional autobiographical memories are surprising in that they occur without any prior intention to recall and their occurrence is usually unexpected. Semantic memories, on the other hand, occur when an individual is engaged in an automatic activity or when attention is divided with another unrelated task.

1.3. Recognition Memory

Recognition memory is a particular aspect of intentional memory, which has been of great importance to cognitive research. Recognition memory can be defined as the ability to recognize and consciously remember previously encountered information (Mandler, 1980). There is a vigorous discussion amongst several prominent researchers whether recognition memory consists of one or two processes.

Accordingly, theoretical perspectives taken by those researchers can be presented in two different main classes; that is, single or dual process models. The following section focuses and summarizes these two models of recognition memory.

1.3.1. Models of recognition memory

Several distinct recognition memory models have been proposed. The models can be categorised as single process models and dual-process models of recognition memory. The distinction between the two models was made according to the emphasis made on the underlying processes (e.g. memory strength, familiarity and recollection) forming recognition memory. Those models classify memory signals as a discrete process (Batchelder & Riefer, 1990; Klauer & Kellen, 2010), a continuous representation (Wixted, 2007), or a mixture of both (e.g.Yonelinas, 1997). In this section models of recognition memory will be explained in detail and discussed.

1.3.1.1. Single Process Models of Recognition Memory

Single process models support the idea that recognition decisions are grounded on the strength of a memory signal relative to a decision criterion set by the individual. In this thesis, three dominant single process models of recognition memory have been reviewed; namely the signal detection theory, matching models and threshold models.

1.3.1.1.1. Signal detection theory

The typical interpretation of signal detection theory involves two Gaussian distributions, one for target items and one for lure items. A decision criterion lays between these two distributions; any test item that generates a memory signal that exceeds this criterion is labelled as ‘old’ and any memory signal that fails to exceed the criterion is labelled as ‘new’. This model assumes a continuous memory process (familiarity). The recognition judgment is based on the comparison of a memory to a criterion. Thus, the average familiarity of a target is greater than the average familiarity of a lure since targets were studied in the specified context.

1.3.1.1.2. Global matching models

The Search model assumes that items are stored separately, each item retrieved and compared against the test item; if there is a match the response would be yes and otherwise, no. However, making a serial search would prolong reaction time for each decision, especially for 'no' responses. Alternatively, the direct access model proposes that such serial search is used in recall, but for recognition a direct access to the relevant node can be granted when the memory is cued by the test word. However, this model doesn't predict that the recognition can be affected by other (non-target or distractor) items. Matching models (e.g.Flexser & Tulving, 1978) focus on the serial or parallel match of the probe item with the memory item, and each decision is made according to the strength of the match. Alternatively, global matching models combine all the strength of the matches and generate a composite value which then contributes to the decision.

1.3.1.1.3. Threshold models

In contrast to signal detection models which assumes a continuum of memory strength, high threshold models define discrete memory states. The high threshold model assumes that there is only one memory state; it is either a recognition, or otherwise a non-recognition. The model puts emphasis on guess responses on the recognition judgement process. The model assumes that an old item will be recognised if it exceeds the memory threshold or on the basis of a guess. If an old item exceeds the memory threshold, it will be correctly identified as old, if it fails it may be identified as old or new depending upon the response bias from non-recognition.

The 2-threshold model assumes that old items which exceed the old recognition threshold will always be identified as old and new items which exceed the new item threshold will always be identified as new and uncertain items will be judged on the basis of a guess. The model asserts that occurrence of false alarms are dependent on new item, a new item will be incorrectly accepted as old if it is not recollected as new. Therefore, the 2-threshold model includes one more parameter than the high threshold model and differentiates the processes behind the occurrence of hits and false alarms by using two memory thresholds for old and new items. Interestingly, if the probability of an old/new item will exceed the old/new recognition threshold is assumed equal, which suggests that the hit rate is composed of a proportion of true recognitions as well as the correct guesses from the uncertain state. Conversely, occurrence of false alarms is only dependent on the uncertainty, the false alarm rate is basically the probability of saying "old/yes" when uncertain. Therefore, recognition bias is highly dependent on the false alarms.

To sum up, threshold models contribute to the theory by including parameters of guess and uncertainty in recognition, discrimination and response bias measurements and threshold of old and/or new items.

1.3.1.2. Dual process models of recognition memory

Research on recognition memory has triggered much contemplation due to its capacity to not rely on merely a single process. Although assuming recognition memory is based on a single process is more parsimonious, behavioural, neuropsychological and neuroimaging studies support the thesis that recognition memory consists of two different processes; familiarity and recollection (often referred to as "knowing" and "remembering"). Recognition expresses itself as the vivid memory of having experienced the same information before (recollection) but can also be linked to the recognition of a feeling of having previously encountered the stimulus in question (familiarity) (Jacoby, Toth, & Yonelinas, 1993; Mandler, 1980, 2008; Yonelinas, 2002). Encountering a stimulus in our daily life, may feel familiar (familiarity) but may not necessarily lead to the recollection of previous experiences relative to that stimulus. The dual-process signal detection model (DPSD;Mandler, 1980; Yonelinas, 1997) is a hybrid approach that combines a continuous familiarity process and threshold component (recollection). Despite the ample research on familiarity and recollection processes, a variety of models exist in the literature. Although, they have similar assumptions, such models also offer some different views about the way familiarity and recollection work. In this thesis six influential dual process models of recognition memory have been reviewed, namely the high threshold/ signal detection model, Mandler model, Jacoby model, Tulving model, Atkinson model, and continuous dual process model.

1.3.1.2.1. High threshold/ signal detection model (HTSD; Yonelinas) model

Yonelinas and colleagues have proposed that two processes (recollection and familiarity) can be differentiated by type of information that they provide (quantitative or qualitative) and how those processes influence recognition confidence. According to this model, recollection is a threshold process where an information should be retrieved; in contrast, familiarity is a signal-detection process in which information has been accepted as having been studied. For instance, recollection requires one to remember detailed episodic information; if one recollects a person's face she will also remember the information about that face, such as the person's name or occupation. Whereas in familiarity, remembered information would be less specific; feeling familiarity to a face requires recognizing a number of pieces of information related to that face, lacking the episodic information. In some situations, people can retrieve different aspects of information such as its temporal or spatial context or associations between different components which are necessary for recollection. However, for some situations people may fail to retrieve qualitative information. When this happens, people are expected to show a tendency to rely on their familiarity assessments. This model proposes both processes are involved in the decision-making process.

1.3.1.2.2. Mandler model

According to this model familiarity and recollection supports different processes; familiarity supports both recognition and implicit tasks whereas recollection supports recognition and recall. Mandler (1980) argues that familiarity and recollection works in parallel but familiarity is faster than recollection.

1.3.1.2.3. Jacoby model

Jacoby and his colleagues suggested that recognition memory judgements may rely on processing fluency (familiarity) or retrieval of an item that has been studied earlier (recollection) and the distinction between the two processes lies in the idea that recollection is a controlled process whereas familiarity is an automatic one (Jacoby, et al., 1993). The two processes are assumed to be independent but to operate in parallel.

1.3.1.2.4. Atkinson model

Atkinson and Juola (1973) aimed to reconcile single and dual process theories and proposed a ‘two-criterion model’, which emphasizes two different criterions; high and low. Familiarity signals are formed when the memory signal falls above a high (old) or below a low criterion (new) value. If the familiarity process falls between high and low criteria, then a search process is initiated. Successful search leads to slower recollection-based decision. Similar to dual-process theory, familiarity and recollection are defined as two processes, however, recollection works as a back-up process activated when familiarity fails to provide an answer. Assessment of studied and non-studied items are based on the activations of the lexical nodes. In a recognition test those nodes are activated and studied items are naturally more active compared to non-studied items. Therefore, evaluation of activation of the lexical nodes is the first step of the recognition, if the activation is ambiguous a search is initiated for further evaluation. This model assumes that familiarity is a fast and perceptual process whereas recollection is a slower semantic based process.

1.3.1.2.5. Tulving model

Tulving and colleagues argued that there are several functionally distinct memory systems including episodic memory which reflects remember (recollection) responses and semantic memory which includes conscious experience of knowing (having familiarity without remembering).

Tulving (1985) defines three main memory systems which were accompanied with three different consciousness levels; episodic, semantic and procedural memory reflects autonoetic, noetic and anoetic consciousness levels, respectively. He argues that it is possible that a person cannot remember an event but he/she may know something about it. Thus, any kind of retrieved information from episodic or semantic memory may be one of remembering (autonoetic awareness) or knowing (noetic awareness), or a combination of both. As a result, he argues that one cannot remember without awareness.

It is important to note that in earlier versions, remember and know responses are considered to be related to recollection and familiarity (Gardiner & Java, 1993).

However recently it has been suggested that recollection and familiarity are independent processes but recognition responses can be made from a combination of both (Jacoby, Yonelinas, & Jennings, 1997; Yonelinas, 1994). Contrarily, remember and know responses are mutually exclusive, because know responses can only be made in the absence of remember response.

1.3.1.2.6. Continuous Dual-Process Model

The common assumption of single process models posits that remember judgements reflect strong memories whereas know judgements reflect weak memories. To challenge, a new model has been formed: continuous dual process model (Ingram, Mickes, & Wixted, 2012). Researchers argued that the assumption of single process models is generally true. However low confidence-remember judgments are associated with lower old/new accuracy, but higher source accuracy, than high confidence- know judgments.

1.3.2. Overview of models

In previous section, three single process models and five dual process models have been reviewed and summarised. In this section those will be compared briefly.

The most obvious difference between two models is that single process models argue that recognition mainly relies on one familiarity process whereas dual process models assumes there are two separate processes underlying recognition; recollection and familiarity.

Comparison of single process models reveal several important distinction between models. First, the underlying process has been accepted to be familiarity or memory strength in signal detection models and recognition (or non-recognition) in global match models, whereas guessing as well as familiarity have been emphasised in high threshold models. Second, global matching theories stress the match between test item and memory representation. However, according to signal detection model recognition is a continuous process.

Most dual-process theories agreed on the assumption that familiarity is a continuous and recollection is a dichotomous process (Atkinson & Juola, 1973; Jacoby, 1991; Mandler, 1980). According to Atkinson's model (Atkinson & Juola, 1973) familiarity is completed prior to the start of the recollection process whilst the models of Mandler, Tulving and Yonelinas assume the two processes to initiate simultaneously (Mandler, 1980; Tulving, 1985; Yonelinas, 1994). The latter models also suggest that during the retrieval of information familiarity and recollection work independently. Finally, some researchers suggest that recollection reflects conceptual processes whereas familiarity reflects perceptual processes (Atkinson & Juola, 1973; Mandler, 1980).

Yonelinas (2002) in his influential review paper pointed out some important agreements among the dual process models (a) familiarity is faster than recollection (b) both processes work independently at retrieval (c) familiarity is a continuous index of memory strength and recollection forms with a retrieval of a specific information (d) recollection reflects conceptual and familiarity reflects perceptual processes (e) recollection reflects controlled and familiarity reflects automatic processes (f) familiarity decreases more rapidly than recollection.

Although there are different models trying to explain the differences between recollection and familiarity, they are considered dissociable processes. Some researchers are investigating different forms of familiarity (Anderson, et al., 2011;

Jacoby, et al., 1993; Ste-Marie & Jacoby, 1993) . In the next section we will concentrate on SR effect.

1.4. Spontaneous Recognition Effect

The spontaneous recognition effect is an aspect of recognition memory that can be regarded as a part of unintentional memories. Occurrence of the SR effect stems from unintentional processing of distractors and involves “taking over” attention unintentionally during intentional target recognition (Ste-Marie & Jacoby, 1993).

Most interference tasks, such as the Stroop and Flanker tasks, focus on the competition between automatic and conscious processes. Manipulations of intentional processing of information in interference tasks allows automatic processes to remain undisturbed (Jacoby, 1991). In order to differentiate and estimate the separate contributions of intentional and unintentional recognition Jacoby (1991) developed the process dissociation procedure. He also suggested that attention demanding tasks are required in order to rule out the intentional processing put in place in order to ignore irrelevant information. (Jacoby, Woloshyn, & Kelley, 1989) conducted a study on the false fame effect to investigate the effects of dividing attention on familiarity compared to conscious recollection. In the study phase of the task, participants read a list of names. Then, in the test phase they decided whether a name was famous or not. Participants were informed that all of the names they had read in the first list in the study phase were non-famous, so if they remember a name from the first list they should be able to know that it was non-famous. In the divided attention condition, participants listened to a continuous string of numbers and searched for three odd numbered digits during test phase. They hypothesized that when attention was divided, participants should be unable to consciously recollect a name that they have read before, and any remaining effect could be attributed to its familiarity. They found that the probability of identifying a name as famous is high when the non-famous name was new (non-famous names that are not in the list) vs. non-famous name was old (non-famous names those are in the list) in full attention condition, whereas it was lower when the non-famous name was new vs. non-famous name was old in divided attention condition. This suggests that dividing attention disrupted the conscious recollection of old non-famous names as studied before and the familiarity created a “false” fame.

Ste-Marie and Jacoby (1993) suggested that the SR effect could be measured via the indirect influence of distracting stimuli on recognition judgements of target stimuli and suggested that dividing attention in a task would decrease correct responses arising from recollection and increase errors arising from unintentional automatic responses. They investigated SR with a Flanker task paradigm which was used to examine the influence of presenting a flanking letter on the time required to judge whether a test letter was a member of a memory set. The centre target word was surrounded by one distractor word above and below the target. Recognition responses were made to the target words whilst ignoring the distractors. The experiment included full and divided attention conditions (Ste-Marie & Jacoby, 1993). They provided participants with a Flanker task which was coupled with a listening task, aiming to divide their attention. They found that in the divided attention condition participants made more false alarms than in the full attention condition. In turn, they demonstrated that they were faster RT levels in the congruent trials, as compared to the incongruent trials in the divided attention condition. They also showed that repeating the words during study and changing the modality of the words from study to test reduced the effects from distractors. Accordingly, it is suggested that familiarity did not produce flanker effects under full attention. As such, the researchers argued that in the divided attention condition participants were not able to make accurate recognition judgements and instead relied more on familiarity judgements because they are less able to make conscious recollection of previously encountered information. Two accounts were suggested for why this distractor effect is larger under divided attention conditions. First, the selective attention account suggests attention is spread more widely under divided attention conditions and thus flankers are processed to a greater extent than under full attention. Second, that divided attention reduces the ability to use intentional recollection and allows the more automatic familiarity processes to dominate recognition memory decisions.

Furthermore, Anderson et al. (2011) suggested that investigating SR effect could be achieved by comparing the influence of old distractors to new distractors on behavioural performance (accuracy and/or reaction time measurements) of recognition judgements for the target stimuli without directly questioning participants about the distractors. In experiment 1 older adults' recognition judgements (hits and false alarms) to word targets were affected by the type of picture distractor (old or new). This SR effect was not shown for younger adults or when pictures were targets. They reasoned that older adults were more likely to process the distractors given their general deprivation of attentional resources. Also, words are less likely to affect performance on picture judgements as pictures are thought to be more salient (possibly due to their relatively larger size compared to words).

Anderson et al. (2011) compared SR effect for older and younger adults on divided and full attention conditions. They used a listening task which required participants to listen to a sequence of numbers in order to divide their attention and respond to a 3-digit odd number that appeared on screen while they were doing a memory Stroop task comprised of old/new targets and old/new distractors. They found that both older and younger adults showed the SR effect in the divided attention condition. They also showed an increase in the false alarms produced by new targets and increase in hits to old targets. Jacoby and other researchers have shown that younger adults can perform similarly to older adults by providing younger adults with an attentional load (e.g. see Balota, Burgess, Cortese, & Adams, 2002; Castel & Craik, 2003; Jacoby, 1999)

Anderson et al. (2011) provided evidence of how unintentional distractor recognition affects intentional target recognition in behavioural level. They argued that the SR effect stems from familiarity responses to distractors. However, it was vital to provide the evidence that participants actually show familiarity to distractors which Anderson et al. (2011) failed to demonstrate. To address this issue, Bergström, Williams, Bhula and Sharma (2016) investigated how unintentional recognition of distractors affected the recognition of target stimuli and whether these processes could be dissociable neurally. They designed two experiments where in experiment 1 they used words as targets and pictures as distractors and vice versa in experiment 2. Behaviourally, they replicated Anderson et al.'s findings. In experiment 1 they found that new distractors decreased the likelihood of recognising old targets as old compared to old distractors, and they found a trend of new distractors facilitated correct rejections of new targets compared to old distractors. However, for experiment 2 where pictures were targets and words were distractors, they failed to find a distractor effect. They compared two experiments and found that distractor effect was significantly different from each other. More importantly, their

EEG results demonstrated the difference between distractor types arises from different recognition mechanisms. Indeed, both old target words and old distractor pictures elicited significantly more positive FN400 amplitudes (which indicates familiarity processes) than new target words and new distractor pictures, whereas a typical increased parietal positivity (which indicates recollection processes) for old compared with new items was only found for word targets. Therefore, they provided important information about the neural processes underlying SR effect. First, they demonstrated that both distractors and targets trigger familiarity related ERPs (FN400), whereas, ERPs indicating recollection are specific to targets. Secondly, this study showed that despite the fact that participants were instructed to ignore distractor items, they unintentionally processed them due to familiarity processes. To sum, their research had several contributions in understanding the processes underlying the SR effect. Behaviourally, they demonstrated that previously seen and non-seen distractors affected the recognition of targets, and that participants made more hits and correct rejections when targets and distractors were congruent compared to when they were incongruent. In addition, they established the difference in the neural processing of targets and distractors. Their results showed that recollection related parietal old-new effect was present only for targets whereas familiarity related FN400 was present for both old targets and old distractors.

Overall, studies investigating SR with different paradigms showed that when attention is divided, SR is more likely to occur. These findings imply attention has an important influence on SR: attention is needed to avoid spontaneous recognition. Previous studies usually required participants to hold numbers in mind during a recognition task in order to ensure divided attention. The use of a secondary task suggests that working memory might potentially play an important role in tasks that demonstrate SR effect. The working memory will be explained and its possible influence on SR effect will be discussed in the next section.

1.5. Working Memory (WM)

Fundamentally, working memory is a system that allows us to hold, maintain and manipulate information. The main role of WM is to reduce individuals' reliance on automatic responses and allow for alternative responses to be represented in mind (Goldenberg, 2001). Therefore, WM has a crucial role in carrying out cognitive processes such as attention, concentration and inhibition whilst it also contributes in changing some automatic responses, understanding language, setting goals, planning, problem solving and decision-making processes (Solso, MacLin, & MacLin, 2004). Most of our physical, psychological and social daily activities are dependent on the performance of WM.

Different models have been proposed in order to explain and increase our understanding about this memory type. In this section, two influential models are explained in detail; Baddeley's multicomponent model of working memory and Cowan's embedded process model of working memory.

1.5.1. Multicomponent Model of Working Memory

Baddeley and Hitch (1974) proposed a working memory (WM) model that pioneered in offering a multi-component approach to the WM as compared to the idea of a unitary store. This model was very successful in giving a composite framework to study cognition. In constructing the WM model, Baddeley originally assumed that the central executive is modality-free, acting as a link between modality dependent slave subsystems (Baddeley & Hitch, 1974). In turn, he proposed three main parts associated with it called, central executive, phonological loop and visuo-spatial sketchpad. However, the researchers later reformulated their model by adding an episodic buffer (Baddeley, 2000). Figure 1.1 shows the schematic representation of their final WM model.

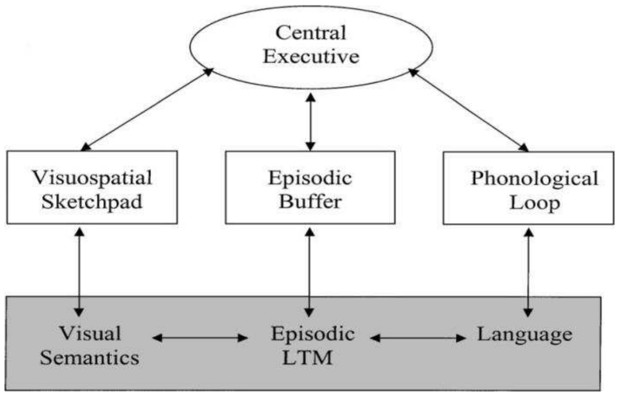


Figure 1. 1. Revised model of working memory reprinted from (Baddeley, 2000).

Phonological Loop

Baddeley (1986) suggested that most tasks involving speech coding in reasoning and comprehension, necessitated phonological coding. Accordingly, he offered the articulatory loop model, wherein he defined phonological coding as speech-based, articulatory coding as speech production and acoustic coding as speech perception (Baddeley, 1986). Phonological loop is one of the slave systems of the central executive, which includes a temporary phonological store. It can hold information with the help of articulatory rehearsal which repeats the information in order to protect it from decay through time. The phonological loop is considered to be evolved for speech perception and production (Baddeley, 2000). The phonological loop comprises two main components: phonological store (holds speech-based information) and articulatory control (process of inner speech with sub-vocal rehearsal).

Visuo-spatial sketch pad (VSSP)

When one tries to recall a picture or scene or imagine a new route the cognitive processes that are utilised to perform these actions rely on the visuospatial sketchpad. This component is responsible for storing visually presented information such as drawings or remembering motor movements. The visuospatial sketchpad contains two structures that create visual imagery: the visual cache and the inner scribe (Logie, 1995, 2003). The visual cache is capable of storing visual information temporarily that comes from perceptual information (Smyth & Pendleton, 1989). Also, it contains shape, colour and spatial information. Whereas, the inner scribe is capable of refreshing stored information and storing kinaesthetic information, the inner scribe manipulates the information kept in the visual cache. Also, it has been showed that the visuospatial sketchpad and the phonological loop are independent systems (Cocchini, Logie, Della Sala, MacPherson, & Baddeley, 2002)

Central executive

The central executive (CE) is the most diligent and important part of the WM model, as it coordinates the activities of the visuospatial sketchpad, phonological loop and episodic buffer. In addition, the CE also links gathered information to the long-term memory via the episodic buffer. Although the CE is not a memory store, it functions as a control system which directs and guides attention and combines, manipulates, and updates information from the sub-systems to maximise the outcome (Baddeley & Logie, 1999).

The transaction between the two different modalities coming from the visuospatial sketchpad and the phonological loop requires the participation of a control system. This communication between two sub-systems is made possible by the central executive.

Episodic Buffer

The episodic buffer (EB) has a limited storage capacity and is responsible for binding information that comes from different dimensions and as such creates integrated episodes (Baddeley, 2000). An integrative buffer was proposed to connect the information between the visuospatial sketchpad and phonological loop into a coherent sequence. EB is fed by perception and WM subsystems and links the information to the central executive. Holding the information temporarily in a multi-dimensional manner allows the EB to combine and bind the information so as to create chunks of episodes that are essential for consciousness.

1.5.2. Embedded Process Model of Working Memory

The Embedded Process Model emphasises the role of attention in WM (Cowan, 1999). According to Cowan (1999), three memory components are (a) activation, (b) the focus of attention and awareness, and (c) long term memory (LTM), all contribute to working memory. WM is controlled by the “focus of attention” that involves two distinctive processes, namely “scope” and “control” of attention. Scope of attention refers to a zooming mechanism whilst “control of attention” determines where attention should be directed.

Moreover, Cowan (1999) distinguished between the activated part of LTM and the focus of attention. The focus of attention is assumed to have limited capacity whereas the activation of representations in LTM is not capacity limited. Information can be processed in the focus of attention without being impaired by holding other information in the activated LTM.

Cowan (1999) suggested that if holding information is necessary for a mental task it is possible that along with the target information, irrelevant information could be held in the WM. During information processing information is held in the focus of attention and if capacity is exceeded, extra information could be held outside of focus of attention. In this model, rehearsal recirculates and reactivates the information in and outside of the focus of attention. In Baddeley's model verbal rehearsal serves to reactivate items in the phonological store. Similar functions are used in Cowan's model, in terms of keeping information in the focus of attention. When information is needed, it is activated in LTM and if there is any additional information added in activated part in LTM, new information combinations are formed which then may become a part of LTM.

1.5.3. Attention and Working Memory

Kane and Engle (2003) suggested that WM is the sum of short term memory (STM) and controlled attention. Their formula suggests that the difference between STM and WM is the controlled attention. Furthermore, it is supported by the research that shows WM tasks usually necessitate control of attention.

Lavie and her colleagues proposed two mechanisms for selective attention to explain the effects of load on attention. The first mechanism is a passive, perceptual selection mechanism that excludes irrelevant distractors from perception in high perceptual load settings. The second mechanism is an active attentional control mechanism that rejects irrelevant distractors in low perceptual load settings (Lavie, 1995; Lavie & Tsal, 1994). This mechanism rejects distractors even if they are perceived and depend on higher order cognitive functioning (De Fockert, 2013). When the higher cognitive systems are loaded, because the capacity for controlling goal directed stimuli would be interrupted, the processing of distractor stimuli could increase. According to this theory, increased perceptual load is expected to reduce distractor interference because the distractors are not perceived to interrupt the goal directed control. The load theory of attention predicts that early selection is expected for high perceptual load, whereas late selection is expected for low perceptual load. (Lavie & Fox, 2000) found that high perceptual load reduced distractor interference on reaction times of target processing which suggests that early selection effects distractor processing in high perceptual load conditions.

Lavie and De Fockert (2005) conducted a series of studies to examine the causal role of WM in distractor rejection during visual search. They suggested that irrelevant distractor rejection should depend on the availability of the WM to maintain goal-directed control in visual search. They hypothesized that if WM for the search task determines attentional capture by an irrelevant singleton, then the singleton interference would be greater in a dual task condition with a high WM load compared to single task condition with no WM load. In their first experiment they compared distraction (attentional capture) from an irrelevant singleton during visual search in single and dual task conditions. The researchers found greater errors and slower RTs for the dual task condition compared to the single task condition. In their second experiment they used the same visual search and added successor naming tasks with high (digits were presented randomly) and low (digits were presented in the same order) working memory loads. They found significantly slower RTs and higher error rates with high WM load than low WM load. Also, the distractor effect was greater in the high WM load condition as compared to the low WM load condition. These findings support the hypothesis that WM is involved in goal directed control of visual selective attention.

Moreover, de Fockert, Rees, Frith and Lavie (2001) argued that WM is essential for reducing distractor effects by maintaining the direction of attention and having control over relevant stimuli. They suggested that higher WM load should increase distractor processing. As such, they manipulated working memory load in a visual “successor-naming” task (i.e. a selective attention task) which involved the classification of famous names as pop stars or politicians whilst ignoring the distractor faces present in a simultaneous WM task that required keeping 5 digits in mind during selective attention task. They found greater interference on RTs from incongruent distractors compared to neutral or congruent distractors under high (vs. low) working memory load. Moreover, the neuroimaging results showed that there was greater activity in frontal cortex which was associated with WM during conditions of high WM load than low WM load. In addition to this, activity in visual cortex related to the presence (vs. absence) of distractor faces was significantly greater under conditions of high compared to low WM load. These results provide further evidence for the load theory of selective attention (Lavie, Hirst, De Fockert, & Viding, 2004).

Connectedly, Conway and Engle (1994) argued that individual differences on measures of "working-memory capacity" reflect the ability to use controlled attention to prevent environmental distractions and interference from events stored in LTM. A variety of studies have demonstrated that individuals who score high on WM tasks are better at inhibiting distractors (Conway & Engle, 1994; Engle, Conway, Tuholski, & Shisler, 1995). Kane and Engle (2003) showed that participants with low WM span made more errors towards a distracting incongruent word in a Stroop paradigm. This suggests that WM capacity is involved in controlling the distractor effects. Similarly, Conway, Cowan and Bunting (2001) asked participants with high and low WM capacity to perform a dichotic listening task in which their own name was presented in the irrelevant message. The results indicated that participants with low WM capacity detected their names more than participants with high WM capacity. Consequently, they argued that low WM capacity resulted in difficulty in blocking out, or inhibiting, distracting information (Conway, et al., 2001).

Lastly, the dual mechanisms of cognitive control (DMC) theory suggest that WM supports the task relevant information by using the ability to alter the responses to particular task demands instead of habitual or automatic responses. Proactive control is conceptualised as the maintenance of task relevant information to control and alter the cognitive processes such as attention, perception and preparation of responses whereas reactive control reflects stimulus-driven goal reactivation, especially after a high interference event is detected. Consequently, proactive control actively anticipates the conflict whereas reactive control comes in after the onset of the interference (Braver, 2012). Therefore, WM resources are required for proactive control to actively maintain goal-related representations (Burgess & Braver, 2010).

1.6. The Spontaneous Recognition Effect and Working Memory

The spontaneous recognition effect occurs when distractor stimuli interrupt a recognition judgement. To avoid the SR effect in an ongoing task it is necessary to ignore distracting stimuli, and goal directed control is crucial in order to resist distracting stimuli in target processing. Goal directed control is to focus attention on goal-relevant stimuli while ignoring irrelevant distractor stimuli. Working memory is necessary to actively maintain goal-relevant information for performing complex cognitive tasks (Baddeley & Hitch, 1974; Miyake & Shah, 1999). Attention and WM could be considered as an important aspect of understanding the SR effect.

The spontaneous recognition effect is an unintentional process that appears when the prior presentation of stimuli affects the recognition judgements. If attention is sufficiently focused on a recognition task, recognition of distractor stimuli may not occur. Previous studies showed that SR effect occurs in a recognition test when attention is divided with another task (Anderson, et al., 2011; Ste-Marie & Jacoby, 1993). In addition, a recent study investigating the influence of unintentional recognition on intentional recognition have used a WM task to divide the participants' attention and demonstrated an SR effect suggesting a link between SR effect and WM (Bergström, et al., 2016).

As predicted by the load theory of the selective attention and cognitive control (Lavie, et al., 2004), cognitive control is necessary to reduce the influence of the distractor in low perceptual load setting and is dependent on WM resources (De Fockert, 2013; de Fockert, et al., 2001). Thus, this account predicts that the SR effect is likely to be observed when the WM resources are limited. Similarly, dual mechanism of cognitive control theory proposes (Braver, 2012) WM is necessary to avoid distractor processing.

1.7. Emotion

1.7.1. Emotional Enhancement of Memory

In our daily routines we experience and store emotional information intentionally and/or unintentionally. Making decisions and remembering information is often infused with emotional information. The question of how emotions affect memory has been of interest for the last decade and is labelled as "Emotional Enhancement of Memory". Emotional enhancement of memory (EEM) could be defined as the memory for emotional stimuli or events. Emotional stimuli are generally processed more vividly, distinctly, and they are less prone to forgetting. This has been demonstrated using a range of stimuli, including words, sentence s and pictures (see Buchanan & Adolphs, 2002; Hamann, 2001, for reviews). Emotions have a widespread influence on memory, they may affect long term memory, working memory, and recognition memory. Below are summarised two models of emotional memory that links working memory and attention with emotional information processing.

Cahill and MCGaugh (1998) modulation model of emotional memory based its hypotheses on the experimental evidence of psychophysiological and neuropsychological studies. The model focuses on the stress-hormone systems and the amygdaloid complex (AC) as important mechanisms of endogenous memory modulating/regulating system which are inactive in neutral events but active in emotionally arousing events (Cahill & McGaugh, 1998). The effect of emotion on memory, and emotional learning have been attributed to the amygdala and the medial temporal lobes (Cahill & McGaugh, 1998; LaBar & Phelps, 1998; McGaugh, 2000), and the contributions of ventromedial/medial prefrontal regions (Bechara, Damasio, Damasio, & Lee, 1999). These areas provide a medium for the limbic system which is known to be involved in emotional processing and dorsolateral cortex which is a crucial area for working memory, decision-making, memory updating and goal-directed behaviour as well as suppression of irrelevant memories. In many situations, emotional stimuli were found to enhance or facilitate memory. A comprehensive investigation of the facilitation effects of emotion on memory was done by Hamann, Ely, Grafton and Kilts (1999). They found emotional pictures were better remembered than neutral pictures. They also showed that the EEM effect is correlated with amygdala activation during encoding. More recently, Kensinger and

Schacter (2006) showed that increased amygdala activity corresponded to the successful retrieval of negative but not of neutral stimuli.

Alternatively**,** Attention Mediation Hypothesis (AMH) has been suggested as a complimentary framework to the modulation model of emotional memory which assumes that emotional memory occurs as a result of delayed consolidation processes. However, according to Talmi (2013) the immediate effects of emotion on memory is overlooked. Therefore, they proposed the AMH (Talmi & McGarry, 2012) to emphasize the underlying cognitive processes of the construction of emotional memories as well as the encoding and retrieval processes. For instance, they showed that attention fully mediated emotional memory enhancement when organization and distinctiveness of stimuli were controlled (Talmi & McGarry, 2012)

1.7.2. Emotional Recognition Memory

Studies have shown that one is more likely to call an item "old" when it is negative compared to neutral, whether the item is actually old or new. Windmann and Kutas (2001) referred to this as "recognition bias induced by negative emotional valence". In their study investigating recognition bias to negative words compared to neutral words, they found that negative old words were recognised better than neutral old words.

Evidence suggests that recognition memory can be modulated by emotional stimuli (Tabert et al., 2001). For instance, Kensinger and Corkin (2003b) found that the remember responses are greater to negative compared to neutral words but know responses are greater to neutral than to negative words. Also, they found recollection was higher for negative than for neutral stimuli, and familiarity was marginally higher for negative than for neutral words. They argued that the emotional enhancement effect is dominated by the increase in remember responses. More specifically, Maratos, Allan and Rugg (2000) found that hits and false alarms were greater for negative words compared to neutral ones. Thus, they showed that the discrimination of neutral words was greater and participants showed response bias such that they were more likely to say “old” to negative words. In contrast, some research has failed to show EEM on recognition memory (Taylor et al., 1998). Sharot, Delgado and Phelps (2004) found that 'remember' judgments were enhanced for emotional pictures, but there was no difference in accuracy (hit rates - false alarm rates) between emotional and neutral pictures.

The EEM also depends on the valence and arousal of the emotional stimuli. A study designed to determine whether the memory enhancement effect is due to arousal or valence asked participants to encode negative (negative in valence and low in arousal), taboo (negative in valence and high in arousal) and neutral word lists. They found that recollection was greater for the taboo words compared to the negative words and was marginally greater for the negative than for the neutral words whereas, familiarity was marginally greater for the taboo words compared to the negative words and was significantly greater for the taboo words compared to the neutral words but there was no significant difference between the negative and the neutral words (Kensinger & Corkin, 2003b).

To summarise, the evidence suggests that EEM for recognition memory affects recollection processes more than familiarity, and arousal of the stimuli is more important for familiarity processes. The studies described above were investigating the EEM effect on recognition memory when the stimuli to be recognised was emotional. Therefore, they were focused on the direct effects of emotion. Inversely, this research was interested in the indirect effects of emotion on recognition memory. The influence of emotion on recognition memory was manipulated by using a secondary task which includes emotional stimuli, but the recognition task included only neutral stimuli. A working memory task was used as secondary task; however, the evidence also suggests emotions might modulate the working memory performance.

1.7.3. Emotional Working Memory (EWM)

The idea that cognition can directly or indirectly modulate our emotional experience is well established. First, the research suggested that the relationship between emotion and working memory is bilateral. Emotions can impair different aspects of working memory performance such as feature binding (Mather et al., 2006) or performance in operation span tasks which measures different components of WM (Schweizer & Dalgleish, 2016). Schweizer and Dalgleish (2016) found that irrelevant negative pictures impaired the performance on the operation span task. In contrast, loading WM may impair emotional stimuli processing. Researchers suggested that the negative distractors take up WM resources for attentional control, and away from memory storage, relative to neutral distractors, resulting in poor performance (Schweizer & Dalgleish, 2016). In a study investigating the role of working memory in decoding emotions with a dual task paradigm which contains WM task (2-back task comprised from letters) and facial expression recognition task, researchers found that working memory load impaired the performance on choosing the emotional label to describe a facial expression (Phillips, Channon, Tunstall, Hedenstrom, & Lyons, 2008).

Attention is a critical process for the central executive's function (Baddeley & Logie, 1999; Engle, et al., 1995; Engle, Tuholski, Laughlin, & Conway, 1999) and it can be affected by the presence of emotional information (Vuilleumier, 2005). Empirical findings on working memory for emotional stimuli come from healthy participants yet, findings are still contradictory (Kensinger & Corkin, 2003a; Kensinger & Schacter, 2006; Mikels, Reuter-Lorenz, Beyer, & Fredrickson, 2008; Perlstein, Elbert, & Stenger, 2002). Kensinger and Corkin (2003a) found no effects of emotional stimuli on working memory (measured by an n-back task) accuracy and only marginal effects on reaction times but a large effect on delayed free recall. Mikels et al. (2008) found that healthy older adults showed better performance on positive compared to negative emotional stimuli, whereas younger controls were better at negative compared to positive emotional stimuli. Kopf, Dresler, Reicherts, Herrmann and Reif (2013) investigated emotional WM in young adults with various difficulty levels of an n-back task. Their behavioural results indicated that there was a significant difference between negative and neutral conditions in only the 2-back and 3-back tasks but not for the 1-back task. This finding further illustrates that cognitive control of emotional stimuli is achievable but as the load on WM increases, it becomes harder to resist the attentional bias of negative stimuli.

Perlstein et al. (2002) used a dual task paradigm in which participants were required to respond if the probe contained the same picture with a preceding one (WM task) and they also indicated whether the stimulus is duplicated in the probe (detection task). Their analysis revealed that emotion no effect on the detection task whereas emotion significantly affected working memory performance; the WM performance was better for positive compared to negative stimuli, contrary to previous research (Kopf, et al., 2013).

2. Methodological approach

2.1. Stroop task

The Stroop task has been developed to observe how salient task irrelevant stimuli can generate failure in the selective attention of the goal (MacLeod, 1991; Stroop, 1935). The Colour-Word Stroop task consisted of a stimulus which is written in the same (congruent) or different (incongruent) name of the colour with the ink colour of the word is written. Typically, the task requires participants to name the stimulus according to its ink colour but not to the meaning of the word.

The Stroop interference effect can be measured by the slower reaction times on incongruent trials (conflict) compared to control trials (e.g. string of letters). In addition to interference, the Stroop task can also demonstrate facilitation which is indexed by the difference in congruent and control trials (Lindsay & Jacoby, 1994).

2.2. Memory Stroop task

Results from early colour-word Stroop research have created an immense interest in different aspects of interference effect. Some researchers separated word and colour features of the stimuli and presented them one on each side of a fixation point. The results showed robust interference effects, suggesting that it is possible to obtain interference without having an integrated stimulus used in standard Stroop task. For example, (Hentschel, 1973) embedded a word with black-white line drawings and asked participants to name the pictures and found the interference of word reading on picture naming. Later, Rosinski, Golinkoff and Kukish (1975) demonstrated the same findings as Hentschel (1973), as they showed that incongruent pictures have very small effects on word reading. These studies suggest that picture-word and colour-word versions of the Stroop task seem to relate to each other.

At the same time, Eriksen and Eriksen (1974) developed the “flanker” task in which irrelevant letters or words presented simultaneously with a centrally located target letter or word. They showed that irrelevant flankers interfered with making the correct decision to the target.

Ste-Marie and Jacoby (1993) approached Flanker task from a different perspective and they used the task to investigate the SR effect. In their study, the centre target word was surrounded by one distractor word above and below the target and participants were asked to give recognition responses to target words whilst ignoring distractors.

Anderson et al. (2011) modified the Stroop task and devised the memory Stroop task to measure the SR effect. In their task participants memorised words and pictures, their attempt to memorisation of stimuli requires intentional effort and activation of episodic memory. Without any delay or distraction period participants were tested based on studied stimuli and non-studied (lures) stimuli. In the test phase, pictures and words were presented on top of each other in the centre of the screen. The crucial part of the test phase includes asking participants to ignore the picture stimuli and focus only on the word stimuli. Such an instruction enables pictures to be transformed into distractors and words to be transformed into targets. This is done to provide a basis for unintentional recognition of distractor pictures. Removing picture stimuli from selective attention and placing it in the centre with the target stimuli results in unintentional recognition of the studied (previously-seen) pictures. Similar to colour-word Stroop task, two conflicting tasks are activated; automatic and unintentional recognition of distractor stimuli and goal-related, intentional recognition of target stimuli.

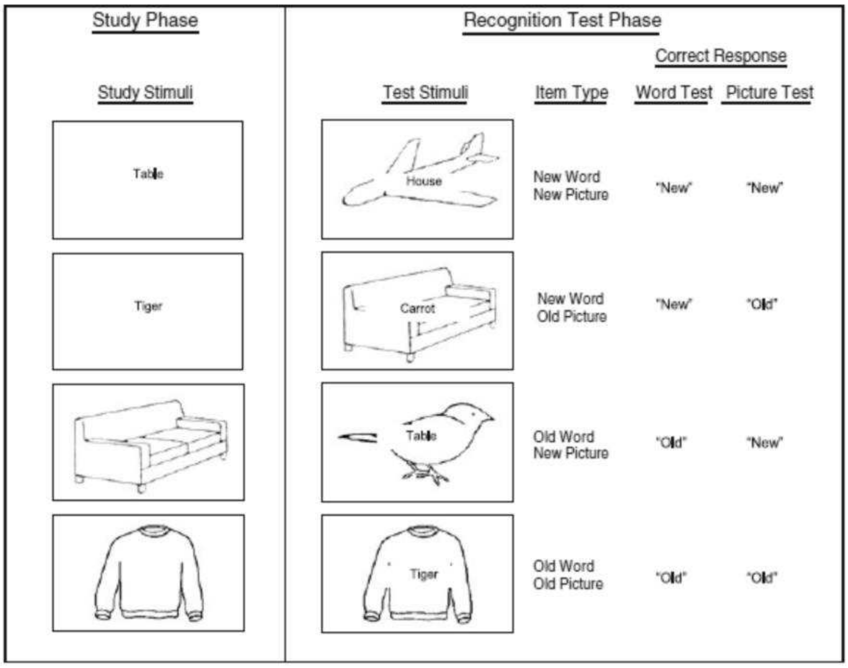


Figure 1. 2. Schematic of the Memory Stroop task. In study phase participants memorise the stimuli then in recognition test phase, they were asked to make recognition decisions based on words or pictures, reprinted from (Anderson, et al., 2011).

There are four possible combinations used in the test phase; old target and old distractor, old target and new distractor, new target and old distractor, new target and new distractor (see Figure 1.2). The task allows one to say whether responses to the target (old or new targets) are affected by the type of distractor (old or new).

2.3. N- back task

It is important to consider how to operationally define and measure WM. Although there are numerous ways to operationalise WM, one of the most popular manipulation of WM is the n-back task especially in neuroimaging studies (Conway et al., 2005; Kane & Engle, 2002). N-back task was preferred to use as a manipulation of WM over traditional WM span tasks because the n-back task can be used with different modalities (visual, auditory) and different loads (1, 2, 3, 4 and more backs). It is possible to use number, picture (activates visuo-spatial sketchpad sub-system of WM) and word (activates phonological loop sub-system of WM) stimuli in n-back task. Most importantly, with n-back task WM load can be manipulated independently from perceptual factors. This advantageous characteristic of the task, allows the manipulation to be controlled for perceptual changes.

The n-back task has been widely used to measure WM and it is a versatile task which is practical to employ in neuroimaging studies and dual task settings. The task enables to manipulate WM load and its response or modality requirements easily relative to complex-span tasks. The load on information maintenance and manipulation increases as the value of “n” increases. Manipulation of WM load is reflected in changes in accuracy and reaction time. High WM load typically results in lower accuracy and slower reaction time than low load conditions (Baddeley & Hitch, 1974; Kirchner, 1958; Ricker, Vergauwe, Hinrichs, Blume, & Cowan, 2015)

N-back task was developed by Kirschner (1958) as a visuo-spatial task with four load factors (0-back to 3-back) to measure “very short term” memory retention, the acquisition and retention of continuously and rapidly changing information. In n-back task, participants were asked if the stimulus on the current trial is the same with the stimulus “n” (0, 1, 2 or more) trials before. In 0-back version, there is only one item needed to be maintained, in 1-back version maintenance of one item and the updating (replacement of one item) is required. However, additional functions are added as the load increases. In 2-back version maintenance of two items in respective order are required as well as updating which includes both shifting and replacement of the previous information. The logical analysis of n-back is represented in the Figure 1.3. Moreover, decision, selection inhibition and interference resolution processes are involved in n-back task (Jonides et al., 1997; Kane & Engle, 2002).

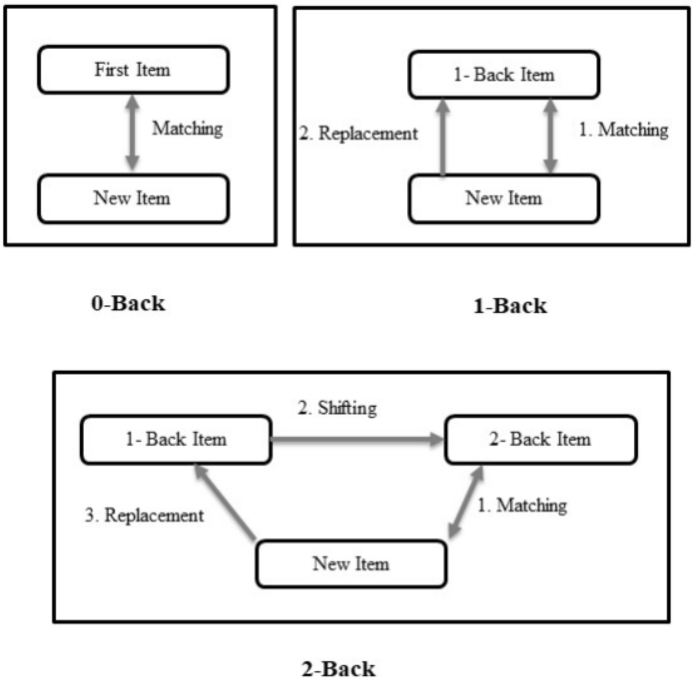


Figure 1. 3. The logical analysis of n-back, adapted from (Chen, Mitra, & Schlaghecken, 2008).

Within this task a target is a stimulus that is the same with the stimulus presented “n” trials before. All other stimuli are referred to as non-targets. The ratio of target/non-target varies, usually ranges from a ratio of 20/80 to 50/50. Additionally, an n-back task consists of match and mismatch trials. A match trial is when an “n” previous trial is the same with the one in the current trial, conversely a mismatch trial is when an “n” previous trial is different with the one in the current trial. Kirschner (1958) initially tested young and old participants with a visual n-back task and found that young and old adults did not differ in 0-back condition whereas old adults performed worse than young adults in one and two back tasks and only a few old adults got as far as to three-back condition.

N-back task is classified neither as a simple-span task nor a complex span task. However, it involves multiple processes such as encoding, shifting, maintaining, and updating. Especially, simultaneous execution of the storage and maintenance functions contributes to the categorization of the task as a WM measure. Studies investigated the correlation between n-back tasks (e.g. spatial and verbal), and complex span tasks (e.g. operation span, spatial complex span and reading span tasks) found non-significant and weak correlations (Campbell, Hill, & Podd, 2012; Kane, Conway, Miura, & Colflesh, 2007; Redick & Lindsey, 2013). In a meta-analysis that compares n-back and other complex span tasks, Redick and Lindsey (2013) found that they are weakly correlated. However they also observed a significant heterogeneity across studies. Redick and Lindsey (2013) argued that complex span tasks and the n-back task should not be used interchangeably as measurements of WM, weak correlation between those tasks imply that they are possibly measuring different constructs of WM. Several arguments have been suggested to explain the discrepancy between n-back task and complex span tasks (CST). Campbell et al., (2012) argued these tasks may assess different subcomponents of WM. In addition, it has been suggested that tasks rely on different memory constructs; n-back tasks rely on recognition memory whereas CST's rely on recall (Jaeggi, Buschkuehl, Perrig, & Meier, 2010). Following this argument, Campbell et al. (2012), argued that correct recall is needed to complete CST and relies on recollection whereas both recollection and familiarity are necessary to perform successfully in n-back task. However, this difference has not yet been described by current WM models. Furthermore, studies showed that n-back task predicts fluid intelligence and executive functions and tasks like Stroop performance, Wisconsin Card Sorting, and verbal fluency (Ciesielski, Lesnik, Savoy, Grant, &

Ahlfors, 2006; Jaeggi, et al., 2010). Additionally, it has been proposed that n-back task is involved in the recognition processes as well as WM related functions (Jaeggi, et al., 2010; Oberauer, 2005). Therefore, n-back task is an appropriate measurement for memory Stroop paradigm since it taps into both recollection and familiarity, and various WM functions.

2.4. Event-related potentials (ERPs)

The electrophysiological measure most commonly used in studies of memory is the event-related potential (ERP). An ERP waveform characterises the average time-locked electrical activity elicited by experimental stimuli. To calculate ERP components, the EEG is segmented and aligned according to the onset of an experimental stimulus. The temporal resolution of ERPs is very high, it is measured in milliseconds, and therefore, they are well suited to addressing questions about the time course of the neural correlates of stimulus-locked cognitive processes.

Memory retrieval studies measuring ERPs demonstrated differences in brain electrical activity between old (studied) and new (non-studied) stimuli. An early report on ERPs of recognition memory demonstrated that ERPs elicited by old items are more positive than new items (Warren, 1980). The evidence of having two memory processes, as assumed by dual process recognition models, has been supported by ERP studies of recognition memory (see Friedman & Johnson, 2000; Rugg, 1995; Rugg & Allan, 2000, for reviews). This old/new effect onsets around 300ms and continues for a couple of more hundred milliseconds. For example, Curran (2004) identified three distinct ERP old/new effects (a) an FN400 that was maximal over anterior, superior and posterior, inferior regions between 300-500ms (b) a mid-frontal old/new effect between 300-500ms which only occurred for pseudo-word recognition (c) P600 was maximal over posterior, superior and anterior, inferior regions which was larger for words than pseudo-words but did not differ between tasks.

Rugg and Curran (2007) found that the ERP markers of recollection (parietal old/new effect) is a phasic, positive-going parietally maximal around 400-500ms post-stimulus onset and exhibits a left-sided maximum. Furthermore, this parietal old/new effect was elicited by all studied items irrespective of the task or recognition accuracy. In addition, an early mid-frontal effect between 300-500ms linked to familiarity processes whereas a later left parietal effect between 400-800ms linked to recollection (Curran, 2004; Rugg, 1995; Rugg & Curran, 2007).

Although some researchers are convinced that FN400 reflects familiarity processes (Mecklinger, 2000; Paller, Voss, & Boehm, 2007; Rugg & Curran, 2007), there is also evidence that frontal N400 is actually indicates semantic priming and it is indistinguishable from functionally identical to centro-parietal N400 component (Kutas & Federmeier, 2011; Voss & Federmeier, 2011). Hence, Voss and Federmeier (2011) showed that semantic priming modulated the FN400, without having an influence on familiarity. This is also supported by findings that N400 do not covary with the recognition for non-semantic stimuli (De Chastelaine, Friedman, Cycowicz, & Horton, 2009; MacKenzie & Donaldson, 2007; Voss & Paller, 2009). On the other hand, recently a study conducted two experiments to differentiate priming from recognition which showed that primed and unprimed old words as well as old and new primed words were not topographically dissociable when priming was embedded in a recognition task, but when priming and recognition was separated, recognition was present at left frontal area of the scalp (Stróżak, Abedzadeh, & Curran, 2016). Considered together, FN400 and N400 are distinct familiarity processes which share similar neural sources. To sum, there are two possible sources of FN400 can be deduced: (a) familiarity-based recognition and (2) semantic/conceptual priming.

Finally, late posterior negative slow wave (LPN) has been observed in a large number of recognition memory studies (Curran, 1999; Cycowicz, Friedman, & Snodgrass, 2001; Donaldson & Rugg, 1998; Dywan, Segalowitz, & Arsenault, 2002; Nessler, Mecklinger, & Penney, 2001) which is an ERP component that onsets before or at around the time the participants respond to a retrieval cue at test which is a bilateral posterior parietal distribution located at Pz (Johansson & Mecklinger, 2003). In addition, LPN was linked to action monitoring triggered after a response conflict (Johansson & Mecklinger, 2003). Alternatively, Herron (2007) identified three different LPNs; two of which was stimulus-locked and third was response-locked. A stimulus-locked early (600-1200ms) effect was found to be sensitive to task fluency and related to the search of episodic information, whereas a late stimulus-locked (1200-1900ms) component was identified for the maintenance of a retrieved episode. A more negative response-locked LPN (50-300ms.) was identified for old items compared to new items that is consistent with the action-monitoring account. As this thesis will explore the recognition of target and distractor items in general, it is also important to include LPN correlate in the investigation of SR effect.

2.5. Recognition Confidence

The ability to evaluate one’s own memory accurately is as important as remembering in normal cognitive functioning. Evaluations of confidence judgements are widely used in eyewitness research. Confidence and accuracy have important applications in legal processes. In addition to face recognition and eyewitness research, understanding the relationship between accuracy and confidence can contribute to knowledge of the cognitive processes governing confidence judgements and meta-memory.

Two types of confidence judgements have been defined; prospective and retrospective. A prospective confidence rating (judgements of learning), is the confidence decisions made when the stimuli is studied before the recognition task and judgements about how well the stimulus is learnt is made. In contrast, a retrospective confidence rating is taken at the recognition task and is about confidence of the person that he/she has made the correct recognition decision. The research included in this thesis will only consider the retrospective confidence decisions of the participants as it will be used as an index of the conscious awareness of the unintentional recognition.

2.5.1. Confidence judgements as an indicator of recollection and familiarity

Confidence judgements are recognised as a measure of one's belief of accurately retrieved information. Confidence judgements are considered to be a marker of recollection and/or familiarity.

According to the signal detection model, the discrimination between old and new items arises by the selection of a response criterion. Ideally, people set a response criterion at the intersection of the old and new item distributions. A way of setting an artificial and standard response criterion for participants would be to ask them to evaluate their judgements on the basis of their confidence. Consequently, a new decision criterion would have been formed.

Alternatively, dual process models attempt to explain confidence of the recognition judgements especially Yonelinas' (1994) dual process signal detection model placed a considerable emphasis on confidence. Recollection is related to high confidence judgements whereas familiarity can be associated with various levels of confidence responses (Yonelinas, 1994, 2001). The Dual process signal detection model makes a critical assumption that lower confidence responses should lead to increases in false alarms, but recollection should remain relatively unaffected (Yonelinas, 2001). This assumption provides a basis for the relationship of confidence and accuracy. High confidence ratings were found to be strongly associated with the items that are previously presented (Boduroglu, Tekcan, & Kapucu, 2014; Busey, Tunnicliff, Loftus, & Loftus, 2000; Clark, 1997) however, the research also disproves the idea that highest confidence ratings produce 100% accuracy (Roediger & DeSoto, 2014). For example, it was found that old responses to words were made more with high confidence compared to low confidence judgements (0.73 vs 0.18) whereas new responses distributed equally for high and low confidence judgements (0.42 vs 0.41) (Henson, Rugg, Shallice, & Dolan, 2000). The research indicates that in addition to accuracy, other possible components might be linked to confidence levels.

The relationship between recognition accuracy and confidence can be described with two main models (Busey, et al., 2000). According to single dimensional models, retrieval processes direct both confidence and accuracy judgements. Using the same resources for both judgements allows one to predict accuracy from confidence or vice versa. Theories of trace strength of memory postulates that memory strengths may vary with different levels of confidence; strong traces are more likely to be recalled and recognised correctly and with greater confidence. In contrast, multi-dimensional model (Busey, et al., 2000) argues that memory traces have two dimensions, memory strength and memory certainty. They jointly affect confidence judgements, whereas recognition accuracy is affected by only memory strength. Also, confidence judgements are found to be closely linked to the strength of the memory representation (Stretch & Wixted, 1998). Having certainty as an additional dimension might make it possible to account for the lack of correlation of confidence and accuracy in some cases.

2.6. Current research questions

This chapter outlined some of the key factors that can influence SR effect, with a specific focus on working memory and confidence judgements. This thesis examined the effects of picture distractors on memory recognition judgements to words when the attention is divided with a working memory task (n-back) in a dual-task paradigm.

The first experimental chapter describes the influence of working memory load and sequential dependencies on SR. To establish the role of the working memory in order in avoiding SR effect, an experiment was conducted with a concurrent secondary task which had two different WM loads (Experiment 1). There is also strong evidence that sequential dependencies involved in recognition memory (Düzel & Heinze, 2002), to understand how it was involved in this specific dual task settings as well as in relation to the distractor processing the data was subjected to further exploration (Experiment 1). Furthermore, the influence of emotions was investigated as their processing can alter the allocation of attentional resources which may influence the occurrence of SR effect (Experiment 2).

Subsequent to exploring the influence of working memory on SR effect, the remaining research questions in Chapter 3 focus on the neural correlates of SR effect using EEG and identify the involvement of working memory. To do so, a replication and an extension of (Bergström, et al., 2016) study was intended. This research was particularly interested in the neural dissociation of the SR effect and the modulatory effects of working memory.

The final research questions in Chapter 4 focus on the impact of the confidence judgements on SR and investigates the neural correlates of subjective confidence decisions. More specifically, the main question in this chapter is "Are people consciously aware of the SR effect when they make recognition decisions for the target decisions?" To investigate this, the experiments included a confidence scale to determine levels of their awareness related to SR effect. Furthermore, a neural investigation of this was conducted using EEG measures in this chapter.

In summary, the current thesis will present six experiments that employ the memory Stroop task in conjunction with behavioural and EEG measures. The aim of the thesis is to provide a new and valuable insight into the influence of unintentional recognition on intentional recognition, as an exploration of the involvement of working memory and consciousness in the distractor bias. The findings from empirical chapters are discussed in the final chapter and suggestions for additional studies are provided that might further explain the SR effect.

Chapter 2

Spontaneous Recognition: Investigating the role of working memory and sequential dependencies

As a requirement to fulfil the demands of the 21st century modern life, people usually had to joggle several tasks at the same time. Along with the goal related processes orchestrating everyday tasks, the ability to ignore irrelevant stimuli is very important to conduct those smoothly. As such, people often are surrounded by distractor stimuli as well as target stimuli. Therefore, the unintentional distraction biases may have an important influence on intentional target recognition. However, research on unintentional recognition has been neglected compared to decades of research on intentional recognition. A limited number of research has focused on the effects of unintentional recognition on intentional recognition (Anderson, et al., 2011; Bergström, et al., 2016; Ste-Marie & Jacoby, 1993) which can also be termed the spontaneous recognition (SR) effect.

SR effect was found under divided attention conditions (simultaneously performing a secondary listening task) in young adults (Anderson, et al., 2011; Ste-Marie & Jacoby, 1993). These results provided support that unintentional recognition govern intentional recognition under divided attention conditions. Two different accounts have been suggested for the role of attention in distractor processing. The first mechanism (perceptual selection) passively excludes distractor stimuli whereas the second mechanism (late selection) actively rejects irrelevant distractors employing attentional control. According to an alternative selective attention account which converged the two mechanisms, perceptual selection mechanism rejects distractor processing in an early stage in high perceptual load situations and the late selective mechanism rejects irrelevant distractors in low perceptual load conditions (Lavie, 1995; Lavie & Tsal, 1994).

However, attention is not the only cognitive process that might modulate the processing of distractors and targets. Working memory (WM) is a system which is important for the maintenance and online manipulation of information and it is a crucial cognitive mechanism that controls attention, prevents distractor processing and inhibits goal-irrelevant information. According to the multi-component model of working memory, the central executive (CE) sub-component is mainly responsible from guiding the attention towards goal-related stimuli. In situations where CE is loaded, goal-related processing might be disrupted and result in attention being misguided. An alternative account of WM portrays a more complex model and emphasises contribution of the activated part of LTM. Accordingly, the embedded process of WM model suggests that focus of attention and the activated part of LTM forms WM, and irrelevant information can be processed in activated part of LTM when the focus of attention exceeded. Therefore, this model predicts that loading WM would allow distractor stimuli to be processed unintentionally (outside of focus of attention). Moving on, the central executive component of WM is responsible for maintaining activation of relevant information and suppressing distractors (Conway & Engle, 1994). Lavie et al. (2004) conducted a series of studies that highlighted the causal role of WM in control of interference with visual distractors. They suggested that loading WM in a selective attention task with a concurrent but irrelevant task reduces the focus of attention on the relevant stimuli with greater interference from distractors.

Thus, Lavie and de Fockert (2005) demonstrated that in an attentional search task interference effect of distractors is greater in high WM load conditions compared to low WM load conditions. Following from this intertwined connection between attention and working memory, it is possible to assume a greater distractor processing when WM is loaded. Especially, in a paradigm like memory Stroop where distractor processing can be observed even with the low perceptual load (one distractor and one target) in divided attention conditions. On the other hand, it is not clear whether divided attention or WM is involved in SR effect as Anderson et al. (2011) used a task which relies on WM functions such as maintenance and updating of information. Therefore, we aimed to understand the involvement of WM in the SR effect.

We have only come across the use of the memory Stroop task by Anderson et al. (2011) and Bergström (2016). Therefore, the main aim of our study was to replicate these findings. We also attempted to generalise these findings by investigating additional manipulations. In all the reported studies we (a) only used words as targets and pictures as distractors. This was done to provide a stronger test of the unintentional nature of the distractors. As Anderson et al. (2011) used pictures or words as targets in different blocks as a within-subject manipulation, it could be argued that when distractor effects were found for word targets the results may be contaminated by intentional memory. That is, checking both the attended and ignored modalities because on some blocks pictures were the relevant target modality. Studying pictures and words and then only testing words as targets with pictures as distractors should be a stronger test of any distractor effects that are driven by unintentional processes. (b) We also used a different secondary task to the one used by Anderson et al. (2011) and Bergström et al. (2016). In particular, N-back task (both 1-back and 2-back) was used to tax working memory resources. The n-back trials were alternated with the memory Stroop trials. It was predicted that the distractor effect would be more likely to appear when using the 2-back task during the test phase as this task is more likely to divert attention away from the main memory Stroop task. When n-back is larger than 1, two contrasting predictions can be made. The higher working memory load for n-back >1 could deplete a common pool of attentional resources and thus allowing the distractor effect to break through. Alternatively, it could be assumed that when n-back>1 recollection is required to decide if the current stimulus matches the stimulus n trials back. If this recollection process competes with the main recognition task for words then this may disrupt the distractor effect that is thought to rely on familiarity. Additionally, n-back task allows the examination of whether the previous n-back decision would affect distractor as an additional factor (Verhaeghen & Basak, 2005). For instance, for 1-back task, a match trial would require less WM resources than a mismatch trial as the mismatch trial requires not only maintaining but also updating the memory record (where there is a requirement to replace old representations with new ones) compared to match trials. Alternatively, for 2-back task, both match and mismatch trials would require update, maintaining and shifting (Chen, et al., 2008). Accordingly, it was found that continuous updating of items in WM prevents strong binding of those items to their contexts in WM, and hence leads to an increased susceptibility to proactive interference (Szmalec, Verbruggen, Vandierendonck, & Kemps, 2011). However, according to some researchers n-back task is considered to be a recognition task as well as a WM task (Jaeggi, et al., 2010). So, match trials would be easier compared to mismatch trials since they would initiate a possibly automatic familiarity response. A match trial in n-back task requires the current stimuli to be congruent (the same) with n-back stimuli. In contrast, a mismatch trial in n-back task requires the current stimuli to be incongruent (different) with n-back stimuli. Therefore, this factor will be called ‘congruency’ in the analysis section.

In sum, our first hypothesis was that participants would make more hits to old targets paired with old distractors compared to new distractors and they would make more correct rejections to new targets when they were paired with new distractors compared to old ones (SR effect). Our second hypothesis was that differences in accuracy defined in the first hypothesis would be higher when the secondary task was a 2-back task (high WM load) compared to 1-back (low WM load). To evaluate, we selected memory Stroop paradigm described earlier as the recognition task as it allows us to examine unintentional recognition indirectly.

This chapter includes two different experiments using the same stimuli, only differing in the number of items encoded in the study phase. Initially, the aim was to investigate whether the change in the quantity of to-be encoded items would affect SR as well as the WM load. Accordingly, an experiment conducted with two episodic loads in different groups. Half of the participants encoded 12 pictures and 12 words whereas other half encoded 6 pictures and 6 words. Later we combined all the data from two groups and included episodic load as a factor. In the next section, the methods and procedure of experiment 1 will be described.

Experiment 1

Methods

Participants

One hundred and two healthy young adults, undergraduate and postgraduate students from the department of Psycho1ogy recruited from the University of Kent. Participants were between 18-48 years old (77 females M_{age}=20.71, SD_{age}=4.40, 21 males M_{age}=24.48, SD_{age}=4.68). The participants were randomly assigned to the 1-back and 2-back conditions. Four participants were eliminated due to failure in their performance on secondary WM task (below 50% accuracy).

Materials

132 words and 132 pictures were used for stimuli. Pictures were single line, simple drawings in black and white and they were taken from (Snodgrass & Vanderwart, 1980) and (Bonin, Peereman, Malardier, Méot, & Chalard, 2003) (http://leadserv.u-bourgogne.fr/bases/pictures/) and words were selected from ELEXICON project database (http://elexicon.wustl.edu/). The words selected by length (3-6 letters), only nouns and concrete words were used. They were presented in blue 60 point Arial font. Pictures and words randomly paired for the memory test with the restriction that the picture and word should not be semantically related.

Procedure

After giving information and having signed the informed consent participants were taken to a quiet room with a computer set up (Dell i5 computer with 15" square screen). The experiment started with a practice with two rounds (each of which included interleaved 10 n-back and 10 Memory Stroop trials) which were designed identical to the real experiment with different stimuli and continued until participants reached at least 80% success. The practice phase followed by the study and test phases. The test phase included the Memory Stroop Task (MST) interleaved with the working memory task. The instructions presented were written in blue on a white background whereas the words were in blue and images were black on white background. The experiment consisted of 5 rounds for high episodic load and 10 rounds for low episodic load condition. This was done to achieve an equal number of trials for both groups. Each round included both study and test phases. Figure 2.1 shows the schema of the design and representative stimuli.

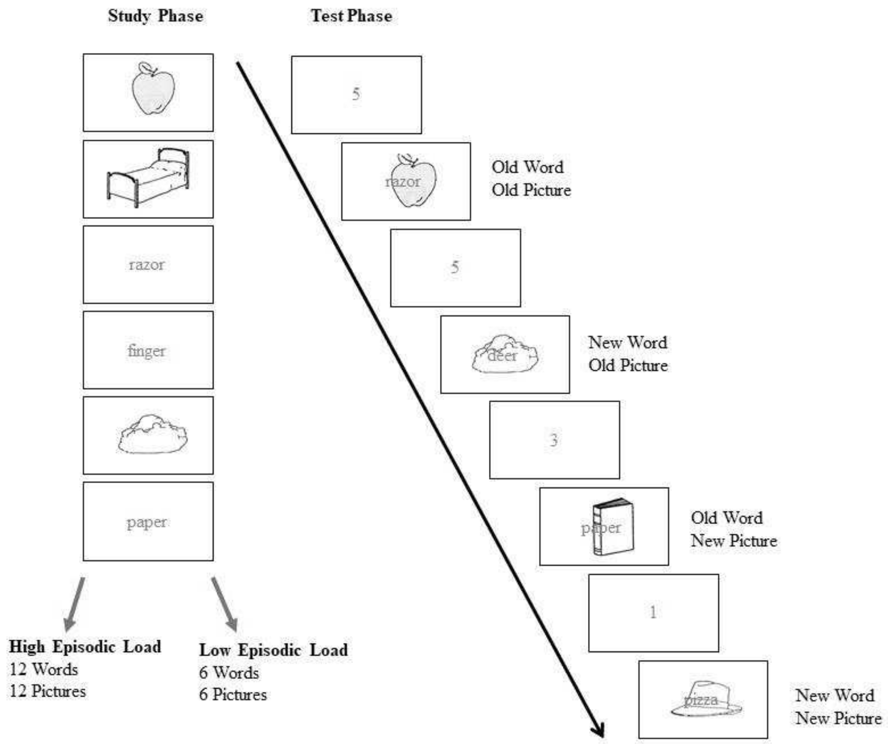


Figure 2. 1. Illustration of the experimental procedure

Participants were shown 12 pictures and 12 words in the high episodic load condition and 6 pictures and 6 words in the low episodic load condition, which were randomly mixed during the study and presented individually. They were asked to memorize the words and pictures. The inter stimulus interval (ISI) was 500ms and the duration of the stimulus was 2500ms. Participants were asked to switch between two tasks during the test phase (see Figure 1); the first task involved making a decision for the n-back task which comprised of numbers. The n-back task is generally used in the literature as a manipulation of working memory (Kirchner, 1958). I used the n-back (1-back/2-back) task in which participants were asked if the number on the current trial is the same with the number “n” (1 or 2) numbers before.

The stimuli were single digits ranging from 1 to 9 and a target was a digit that was the same as the digit presented 1 or 2 (1-back and 2-back, respectively) trials before. All other digits were referred to as non-targets. Target and non-targets were assigned pseudo randomly with the condition of maintaining target/non-target ratio. Each of the blocks contained (50%) targets and (50%) non-targets. Participants were instructed to press the ‘S’ (for same) or ‘L’ (for different) keys. Behavioural outputs were reaction times and response accuracy (hits and false alarms). The second task, the memory Stroop task (MST), closely followed the design used by (Anderson, et al., 2011) In this task, participants are required to make recognition (old/new) judgements on the words when displayed simultaneously with the pictures. Pictures and words were randomly paired and pairings were different across all participants. Each test block included 24 trials for the low episodic load condition and 48 trials for the high episodic condition with a word superimposed on a picture and presented in a random order. Each test block was made up of an equal number of the four target/distractor item types: new words and new pictures (6 trials for low, 12 trials for high episodic memory load), new words and old pictures (6 trials for low, 12 trials for high episodic memory load), old words and new pictures (6 trials for low, 12 trials for high episodic memory load) and old words and old pictures (6 trials for low, 12 trials for high episodic memory load). Participants were instructed to ignore the pictures and make their recognition judgements only for the oldness of the words (did you see the word before in the study phase or not). Participants were instructed to press the ‘S’ button (for old) if they saw the word in the study phase or ‘L’ button (for new) if they saw the word in the study phase. The screen showing the test items was presented until the response or for a maximum of 6000ms. After 500ms ISI, a single digit was presented for n-back task. Participants were asked to respond as accurately as possible. Stimulus presentation and response collection was conducted with an open source computer programme developed by Jonathan Pierce (PsychoPy 2.0).

Results

The design of the statistical analysis was a 2 (target type: old, new) x 2 (distractor type: old, new) x 2 (working memory load: 1-back, 2-back) x 2 (congruity: match, mismatch) x 2 (episodic load: low, high) mixed factorial ANOVA with target type, distractor type and n-back trial was within subjects and working memory load and episodic load was between subjects factor.

Analysis of N-Back task

The n-back performance accuracy and reaction times (RTs) were compared with 2 (episodic load; low, high) x 2 (WM load; high vs low) x 2 (congruency; match, mismatch) mixed factorial ANOVA with congruency as within and WM load and episodic load as between subjects factors. Analysis on accuracy revealed that there was a significant difference between 2-back (M=0.88, SD=0.08) and 1-back (M=0.94, SD=0.08; $F(1, 94) = 11.29$, $p=0.001$, $\eta p^2 = 0.11$). However, there was no difference between high and low episodic load ($F(1, 94) = 0.84$, $p=0.36$), and no interaction of WM load and episodic load conditions ($F(1, 94) = 0.10$, $p=0.76$). Interestingly, congruency and WM load interacted ($F(1, 94) = 11.14$, $p=0.001$, $\eta p^2 = 0.11$). Independent samples t-test separately conducted for match and mismatch trials. Analyses revealed that there was a significant difference between 1-back and 2-back conditions in match ($M_{1\text{-back}}= 0.92$, $SD_{1\text{-back}} = 0.09$; $M_{2\text{-back}} = 0.83$, $SD_{2\text{-back}} = 0.10$; $t(96) = 4.58$, $p<0.001$) but not in mismatch trials ($M_{1\text{-back}}= 0.96$, $SD_{1\text{-back}} = 0.09$; $M_{2\text{-back}} = 0.93$, $SD_{2\text{-back}} = 0.09$; $t(96) = 1.26$, $p=0.21$).

Analysis on RTs revealed that there was a significant difference between 2-back (M=1534ms, SD=58ms) and 1-back (M=864ms, SD=55ms; $F(1, 94) = 70.46$, $p<0.001$, $\eta p^2 = 0.43$), and between low (M=1041ms, SD=41ms) and high (M=1333ms, SD=61ms) episodic load ($F(1, 94) = 12.76$, $p=0.001$, $\eta p^2 = 0.12$), and no interaction of WM load and episodic load conditions ($F(1, 94) = 2.56$, $p=0.11$). Interestingly, congruency and WM load interacted ($F(1, 94) = 4.15$, $p=0.05$, $\eta p^2 = 0.04$). Independent samples t-test separately conducted for match and mismatch trials. Analyses revealed that there was a significant difference between 1-back and 2-back conditions in match ($t(96) = 7.70$, $p<0.001$) and in mismatch trials ($t(96) = 7.72$, $p<0.001$).

The difference between 1-back and 2-back WM load conditions on accuracy and RTs show that manipulations for WM load have been implemented. Furthermore, the results indicated that match and mismatch trials affected the n-back accuracy performance differentially; participants were more accurate in match trials compared to mismatch trials in 1-back task, but the accuracy in match and mismatch trials were similar for 2-back task.

Analysis of Memory Stroop task

Mean scores and standard deviations of accuracy were calculated for oldness (new and old) of target and distractors at each WM load condition (1-back and 2-back) and congruity which can be seen in Table 2.1.

Table 2. 1. Mean and Standard deviation of hit and correct rejection scores for episodic load conditions.

Episodic Load			Old Target		New Target	
	WM load	Congruity	Old Distractor	New Distractor	Old Distractor	New Distractor
High	1-back	Match	0.79 (0.15)	0.76 (0.18)	0.84 (0.16)	0.90 (0.17)
		Mismatch	0.75 (0.18)	0.74 (0.22)	0.88 (0.13)	0.89 (0.12)
	2-back	Match	0.80 (0.17)	0.67 (0.19)	0.77 (0.18)	0.87 (0.11)
		Mismatch	0.76 (0.15)	0.74 (0.20)	0.81 (0.15)	0.82 (0.16)
Low	1-back	Match	0.86 (0.13)	0.84 (0.16)	0.96 (0.09)	0.96 (0.08)
		Mismatch	0.86 (0.14)	0.84 (0.18)	0.96 (0.07)	0.97 (0.11)
	2-back	Match	0.85 (0.19)	0.84 (0.14)	0.89 (0.15)	0.94 (0.10)
		Mismatch	0.88 (0.14)	0.83 (0.19)	0.88 (0.17)	0.92 (0.13)

Analyses revealed a main effect of target ($F(1,94) = 28.52$, $p<0.001$, $\eta p^2 =0.23$), interaction of target and distractor ($F(1,94) = 21.62$, $p<0.001$, $\eta p^2 =0.19$), and target, distractor, congruity interaction ($F(1,94) = 3.88$, $p=0.05$, $\eta p^2 =0.04$), all other main effects and interactions were non-significant ($Fs<1$, $ps>0.09$)

As predicted, target and distractor interacted with WM load ($F(1, 94) = 4.24$, $p=0.04$, $\eta p^2=0.04$). To understand the three-way interaction, two separate ANOVAs conducted for 1-back and 2-back conditions, results revealed that, target and distractor interaction was non-significant in 1-back condition ($F(1, 49) = 3.44$, $p=0.07$, $\eta p^2=0.07$) whereas it was significant in 2-back condition ($F(1, 45) = 22.03$,

$p<0.001$, $\eta p^2=0.33$). Paired samples t-test revealed that participants were more accurate to old targets paired with old distractors (M=0.83, SD=0.15) compared to new distractors (M=0.77, SD=0.18; $t(46) = 2.68$, $p=0.01$), and new targets paired with new distractors (M=0.89, SD=0.11) compared to old distractors (M=0.84, SD=0.15; $t(46) = 4.27$, $p<0.001$).

Interestingly, target, distractor, congruity and episodic load interaction ($F(1, 94) = 7.81$, $p=0.006$, $\eta p^2= 0.08$) was significant. To investigate, 2 (target type) x 2 (distractor type) x 2 (congruity) repeated measures ANOVA was conducted separately for high and low episodic load conditions collapsed for WM load conditions. Target, distractor and congruity interaction was non-significant in low episodic load condition ($F(1, 50) = 0.43$, $p=0.52$, $\eta p^2= 0.008$) but significant in high episodic load condition ($F(1, 46) =8.59$, $p=0.005$, $\eta p^2=0.16$). Further, 2 (target type) x 2 (distractor type) repeated measures ANOVA conducted separately on match and mismatch trials for only high episodic load condition. Analysis revealed a significant interaction of target and distractor in match trials, ($F(1, 46) =23.75$, $p<0.001$), but not in mismatch trials, ($F(1, 46) =0.90$, $p=0.35$). Participants were better at recognising old targets paired with old distractors (M=0.79, SD=0.16) compared to new distractors (M=0.72, SD=0.19; $t(46) = 3.62$. $p=0.001$) and new targets paired with new distractors (M=0.89, SD=0.15) compared to old distractors (M=0.80, SD=0.17; $t(46) = -4.11$. $p<0.001$). See Table 2.2 for results of ANOVA.

Table 2. 2. ANOVA results for Memory Stroop recognition accuracy

Source	F (1,94)	p	ηp²
T	**28.52**	**<0.001****	**0.23**
T * E	0.14	0.71	0.002
T * WM	1.95	0.17	0.02
T * E * WM	0.04	0.85	<0.001
D	0.04	0.85	<0.001
D * E	0.06	0.81	0.001
D * WM	0.04	0.85	<0.001
D * E * WM	1.20	0.28	0.01
C	<0.001	0.98	<0.001
C * E	0.005	0.94	<0.001
C * WM	0.03	0.85	<0.001
C * E * WM	0.12	0.73	0.001
T * D	**21.62**	**<0.001****	**0.19**
T * D * E	2.81	0.10	0.03
T * D * WM	**4.24**	**0.04***	**0.04**
T * D * E * WM	0.35	0.56	0.004
T * C	<0.001	0.98	<0.001
T * C * E	0.93	0.34	0.01
T * C * WM	2.98	0.09	0.03
T * C * E * WM	0.19	0.66	0.002
D * C	0.55	0.46	0.006
D * C * E	0.06	.802	0.001
D * C * WM	0.12	0.74	0.001
D * C * E * WM	1.31	0.26	0.01
T * D * C	3.88	0.05	0.04
T * D * C * E	**7.81**	**0.006***	**0.08**
T * D * C * WM	0.81	0.37	0.01
T * D * C * E * WM	1.74	0.19	0.02

T= Target, D=Distractor, C= Congruity, WM= Working Memory Load, E= Episodic Load, *p<0.05, **p<0.001

Discussion

This study aimed to replicate the results from Anderson et al. (2011) using the same memory Stroop Task which was used to determine how the picture distractors (old or new) influenced recognition of old and new word targets. Our study is in line with previous studies investigating the influence of old compared to new distractors on target recognition (Ste- Marie & Jacoby, 1993; Anderson et al., 2011; Bergström et al., 2016). Specifically, participants were more accurate in recognising the old targets paired with old distractors compared to new distractors and were better at correctly rejecting new targets when paired with new distractors compared to old distractors.

Extending previous research, we provided evidence for involvement of WM on SR effect; target and distractor interaction was modulated by the WM load. Where the secondary task was less demanding in WM resources, participants did not show the SR effect even though they divided their attention for the 1-back task. On the contrary, more demanding high WM load task divided attention sufficiently and allowed unintentional recognition of distractors influence the target recognition. The results suggest that WM resources were required to avoid unintentional Stroop-like effects of distractors. Specifically, high WM-related cognitive demand reduced the ability of participants to reject distractors actively.

More broadly, our results are consistent with the load theory of selective attention: in low perceptual load settings attentional control mechanism rejects distractors actively and this mechanism depends on higher cognitive processes such as WM (Lavie, et al., 2004). As such, in this experiment when the WM was loaded with 2-back task, attentional control was reduced and it was insufficient to stop the unintentional processing of the distractor. The 2-back task created, unlike the 1-back task, enough effect to divide attention and resulted in participants being less able to resist distractor effects and retrieve relevant information encoded in the study phase. This finding supports earlier studies investigating the role of WM on distractor effects (de Fockert, et al., 2001; Kane & Engle, 2003; Lavie, et al., 2004).

Contrary to the predictions, unintentional recognition of distractors influenced target recognition if the previous n-back trial was a match only in high episodic load condition. This finding is especially interesting because the influence of high episodic load on SR effect was revealed only in match trials. The combination of the high load on episodic memory and the cognitive processes required for match responses created a stronger SR effect similar to the effect of high load on WM. There is a possibility that the recognition processes underlying n-back task (especially in match trials) might conflicted/competed with memory Stroop task leading a stronger influence of unintentional distractor processing. However, an additional episodic load might be necessary for this competition to emerge.

Connectedly, participants were also less accurate in 2-back compared to 1-back task on match trials but not on mismatch trials. This suggests that possibly, participants found match trials harder compared to mismatch trials in 2-back task, leading them to be influenced by unintentional recognition of distractors. It has been suggested that n-back task also include recognition processes especially familiarity in match trials, (Jaeggi, et al., 2010; Redick & Lindsey, 2013). This suggests that familiarity responses may help participants in giving an accurate answer in match trials. However, in dual task conditions like our paradigm, a concurrent recognition task may have disrupted this process and conflicted with match trials more in 2-back than 1-back task. As a result, participants were less accurate in match trials compared to mismatch trials. Moreover, this effect was seen on only in high episodic load condition where the to-be encoded items were more than high episodic load condition. According to Cowan (1999), activated part of LTM is a part of WM, and the number of items to be recalled is related to the capacity of WM. Therefore, asking participants to recognize an item amongst 12 encoded items naturally harder from recognizing an item amongst 6 encoded items. Alternatively, global matching models argue that to make a decision it is necessary to evaluate and combine the strength of each related item stored in memory (Clark & Gronlund, 1996; Gronlund & Ratcliff, 1989; Ratcliff, Sheu, & Gronlund, 1992). Therefore, this kind of recognition decision with more items to be matched in episodic memory might be more prone to errors. Furthermore, according to the search model of recognition memory, making a serial search prolongs the response time, as a result, more items would require longer search.

Nevertheless, the results highlight the unintentional nature of the distractor effect as only words were used as targets throughout the study and still the picture distractors affected performance.

Sequential Dependencies

So far, the presented experiments have focused only on the evidence associated with current target recognition. As such, in an analysis interested in the current target recognition generally assumes that the trial "n" is independent from previous trial "n-j" (j>0, lag). However, it is also possible to assume a correlation between "n" and "n-j" that represents sequential dependencies. Malmberg and Annis (2012) argued that memory researchers did not report any findings related to sequential dependencies, and perceived sequential dependencies as random noise. However, the research increasingly showing that sequential dependencies are more than a random noise, and it is suggested to take into account in experimental designs (Düzel & Heinze, 2002). A positive correlation between current trial (n) and previous trial (n-j) referred assimilation and a negative correlation referred contrast. Holland and Lockhead (1968) model for sequential dependencies accounts for assimilation and contrast effects. According to their model, the difference between the previous and the current stimulus would be underestimated on average and current response would be biased towards (assimilation) or away (contrast) from the previous stimulus. Alternatively, Treisman and Williams (1984) argued that the assimilation occurs when the decision criterion in trial “n” followed by the response on trial “n-j”, and contrast results from the stabilization of the criterion to the fixed position for longer sequences.

Early work on sequential dependencies demonstrated reaction time measurements are affected by the preceding item types in choice tasks. For example, Ratcliff and Starns (2009) found responses followed an “old” response compared to responses followed a “new” response created a large difference in zROC slopes. Their results showed that the “new” decision criteria were higher when the previous response was “old” and the “old” decision criteria were higher when the previous response was “new”, illustrating a contrast effect. Düzel and Heinze (2002) observed sequence dependencies on correct rejections which were lower for change (different from previous trial) trials compared the no-change (same with the previous trial) trials but they failed to find a difference in hits. Their findings suggest new item recognition was influenced by the context of preceding old items. For example, participants are more likely to overestimate the current stimulus if its intensity is less than the stimulus presented on the previous trial.

We reasoned that if match and mismatch trials of the WM task can moderate the SR effect then other sequential effects might also occur. Consequently, we investigated the sequential dependencies to further explore the distractor effect. We investigated whether the previous trial context (whether the previous trial was a new/old target or a new/old distractor) affects current trial recognition performance.

It might be predicted given the modality effects found by Ste-Marie and Jacoby (1993) that the old/new nature of the previous word target is more likely to affect the current trial target recognition responses as they are both from the same modality. The old/new nature of the previous distractor picture might not affect the current word target responses. However, it is possible that the previous distractor could interact with the current distractor as their modalities are the same.

Results

The analysis included target and distractor as within subjects factors, as in the previous analysis conducted in this chapter. Consequently, a main effect of target, and target and distractor interaction were also found in analysis for sequential dependencies (see Table 2.4 for details). Therefore, these findings were not reported here again. In addition, in the previous analysis there was no difference of SR effect between experiments and there was no prediction related to sequential dependencies and WM load. Therefore, to have a simpler analysis we excluded between subjects factors (WM load and Experiment) from this analysis.

Mean scores and standard deviations of accuracy were calculated for oldness (new and old) of target and distractors for current and previous target and distractors which can be seen in Table 2.3.

Table 2. 3. Mean and Standard deviation of hit and correct rejection scores combined for all experiments and WM load conditions.

		Old Target		New Target	
		Old Distractor	New Distractor	Old Distractor	New Distractor
Previous Old Target	Previous Old Distractor	0.78 (0.22)	0.77 (0.22)	0.89 (0.18)	0.91 (0.14)
	Previous New Distractor	0.85 (0.18)	0.75 (0.24)	0.88 (0.17)	0.92 (0.12)
Previous New Target	Previous Old Distractor	0.81 (0.21)	0.79 (0.20)	0.86 (0.18)	0.91 (0.15)
	Previous New Distractor	0.83 (0.18)	0.82 (0.19)	0.89 (0.16)	0.90 (0.18)

Subsequently, a 2 (target; old, new) x 2 (distractor; old, new) x2 (previous target; old, new) x2 (previous distractor; old, new) repeated measures ANOVA was conducted to investigate the sequential dependencies of the memory Stroop task.

Analysis revealed a significant four-way interaction of target, distractor, previous target and previous distractor (See Table 2.4). A subsequent 2 (target; old, new) x 2 (distractor; old, new) x2 (previous distractor; old, new) repeated measures ANOVA was done on previous old and previous new targets separately. Results indicated that the interaction of target, distractor and previous distractor was significant for previous old targets (F (1,96) = 6.30, p=0.01, ηp^2= 0.06), but not for previous new targets (F (1,96) = 2.18, p=0.14, ηp^2= 0.02). Following, a 2 (target;

old, new) x 2 (distractor; old, new) repeated measures ANOVA was done on previous old and previous new distractors separately. Results showed a significant target and distractor interaction for new previous distractors ($F(1,96) = 23.18$, $p<0.001$, $\eta p^2= 0.19$), but not for old previous distractors ($F(1,96) = 1.48$, $p=0.23$, $\eta p^2= 0.02$). Finally, a paired samples t-test on current targets and current distractors revealed that participants were more accurate to old targets paired with old distractors compared to new distractor ($t(97)= 4.06$, $p<0.001$). Similarly, they were more accurate to the new targets paired with new distractors compared to new targets paired with old distractors ($t(97)= 2.91$, $p=0.005$)

Table 2. 4. ANOVA results for Memory Stroop recognition accuracy

Source	F (1, 95)	p	ηp^2
T	**30.97**	**<0.001***	**0.25**
D	0.06	0.81	0.001
PT	1.07	0.30	0.01
PD	**5.49**	**0.02***	**0.06**
T * D	**12.69**	**0.001***	**0.12**
T * PT	**7.34**	**0.008***	**0.07**
D * PT	2.10	0.15	0.02
T * D * PT	**5.74**	**0.02***	**0.06**
T * PD	2.24	0.14	0.02
D * PD	**4.19**	**0.04***	**0.04**
T * D * PD	0.91	0.34	0.009
PT * PD	0.08	0.78	0.001
T * PT * PD	0.51	0.48	0.005
D * PT * PD	050	0.48	0.005
T * D * PT * PD	**7.97**	**0.006***	**0.08**

T= Target, D=Distractor, PT= Previous Target, PD= Previous Distractor
*p<0.05, **p<0.001

Discussion

The results on sequential dependencies provided important information on SR effect. Results showed that the recognition of the previous targets and distractors affected the recognition of current targets. The results are especially informative since the results further illustrates the unintentional nature of the SR.

Importantly, a four-way interaction of target, distractor, previous target and previous distractor was found. Investigation on the interaction revealed that SR effect was present when the previous target was old and the previous distractor was new. This finding can be interpreted in the frame of contrast and assimilation effects. Assimilation of previous targets influence current targets leading an increased likelihood of responding ‘old’ if current target is old, and contrast of previous targets influence current targets leading an increased likelihood of responding ‘new’ if current target is new. Moreover, assimilation or contrast effects were not present for previous new targets. At the same time, previous distractors create contrast effect that occurs when the current response is biased away from stimuli presented on earlier trials (Holland & Lockhead, 1968; Treisman & Williams, 1984). Thus, errors tend to be overestimated if previous stimuli are small and underestimated if previous trials are large. New previous distractors assimilate with current new distractors when the current target is new; increasing the likelihood of responding ‘new’. Contrarily, previous new distractors contrast with the current old distractors when the current target was old; leading to an overestimation of the current old distractors, increasing the likelihood of responding ‘old’.

In a study researchers had subjects study a long list of landscape photos and tested memory using a confidence rating procedure (Schwartz, Howard, Jing, &

Kahana, 2005). They found that the highest confidence “old” rating was about 4% more likely to be used on trial n + 1 if it was used on trial n. Their results suggested that assimilation occurs because when an item is collected from memory the representation of the other items from the memory list are activated. When a previous item has already been collected, the next item is more ready to be recollected and more likely to be called ‘old’ with a high confidence. Similarly, Malmberg and Annis (2012) found that probability of a hit was greater following a hit than following a miss. As such, in this experiment, SR effect was observed only when previous pair was of an old target and a new distractor. This finding suggests a contrast of the previous distractors with current distractors. The new distractor is smaller than the old current distractor in terms of familiarity which would lead to an overestimation of the current old distractor. In turn this increases the likelihood of old current target to be called ‘old’. Conversely, the new distractor leads to an underestimation of the new target when it was paired with an old distractor. As an additional factor, previous old target also might lead to an underestimation of the new target leading an increased likelihood of calling a new target ‘new’. However, it should be considered that this experiment differs from previous research investigating sequential dependencies by including the sequential dependencies of both targets and distractors.

The results contribute to the knowledge of SR effect with providing evidence on sequential dependencies. These results were especially important since such an influence has never been reported on SR before.

General Discussion

In our daily lives, we are often surrounded by distractor stimuli that are not in our focus as well as target stimuli that are processed intentionally and have importance for our goals. To ignore distractor stimuli and focus on our current goal is an essential ability for completing everyday tasks. We have reported two experiments on the effects of WM on spontaneous recognition of a distractor item. First, a replication of previous research was aimed and then results on WM extended the previous research. Furthermore, for the first time, sequential dependencies of the SR effect were explored.

The methodology of the studies reported in this thesis specifically allowed us to investigate concurrent WM load on SR effect. Different from previous research, using n-back task as a secondary task ensured the continuous maintenance of the n-back stimuli in the WM. The WM task had the same load in each trial with the exception of the difference between match and mismatch trials. However, in Anderson et al's study, participants heard a string of digits in which they were asked to respond when they detect three consecutive odd numbers (e.g. 5, 7, 9). This could lead to discrepancies in WM load in each trial. For instance, participants might need to hold only one digit, or two depending on the location of the number in the sequence, alternating the WM load in every trial.

Moreover, the main manipulation in the Anderson et al. study was the presence of the secondary task, which was only included in the divided attention condition but not in full attention condition. Therefore, the divided attention condition required participants to complete a dual task paradigm as compared to the single task in a full attention condition in which they only completed the recognition task. Contrarily, our paradigm required participants to divide their attention between two tasks in both WM load conditions. The paradigm used in this experiment was a dual task paradigm. Hence, Lavie and de Fockert (2005) showed that the interference of distractor is greater under dual-task conditions compared to single task conditions. These findings suggest that availability of WM is an important determinant of interference effect of distractor which is more pronounced in dual task conditions.

Experiment 2

Spontaneous Recognition: Investigating the role of Emotional Working Memory

Experiment 1 investigated the effects of WM load on distractor effect in healthy young adults. In the light of previous studies (Anderson, et al., 2011; Bergström, et al., 2016; Ste-Marie & Jacoby, 1993), a dual task paradigm was used in this research to divide the attention between a WM task (the n-back task) and a recognition task (memory Stroop task). Two different loads (1-back and 2-back) were used for the secondary WM task to investigate the involvement of WM processes in SR effect. Analysis on accuracy showed that participants were more accurate when old targets paired with old distractors compared to new distractors and when new targets paired with new distractors compared to old distractors only in the 2-back task. To sum, results indicated unintentional recognition of distractor affected intentional recognition of target and this effect emerged when WM load was high. This finding implies that WM load should be high enough to divide attention and in order to observe SR.

As noted earlier, SR effect occurs from the unintentional recognition of distractors. So far, the influence of unintentional distraction on target recognition was investigated using pictorial stimuli presented at the same time with target stimuli. However, distraction might also occur from factors such as the arousal or the valence of emotional stimuli. In such cases, emotional stimuli attracts attention away from target processing and uses attentional resources for the processing by employing amygdaloid complex (Adolphs, Tranel, & Buchanan, 2005).

In a recognition task, negative emotional words were found to be associated with remember responses than neutral words, but no difference in remember and know responses were found for neutral words suggesting that emotional stimuli elicit recollection rather than familiarity (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003b; Ochsner, 2000). Connectedly, source memory judgements for emotional words were found be more enhanced than neutral words (Doerksen & Shimamura, 2001). However, there is also evidence showing enhanced recognition stems from response bias rather than recollection (Dougal & Rotello, 2007). Nevertheless, emotional information influence recognition for target and non-target recognition. Herron (2017) demonstrated that response accuracy and reaction times associated with targets were unaffected by valence, negative non-targets and new items were both associated with an increased false alarm rate and longer RTs than their neutral items suggesting non-target recognition is affected by emotion. Emotional processes are involved in sensory events, but also elicit adaptive responses and modify perception. For instance, Taylor et al. (1998) found that emotionally salient stimuli appeared to enhance processing of early sensory input during visual recognition.

Especially in the Stroop task, interference is observed when emotion is irrelevant to the task. This interference suggests that people are very sensitive to emotional meaning, and unable to fully ignore such meaning under these conditions. Task irrelevant emotional stimuli modulates attention. The work on SR effect showed that dividing attention enhances SR effect in young adults, researchers argued that this stems from the executive attention and control of task irrelevant distractor processing. In a recognition task like memory Stroop task, the control of attention is especially important to avoid unintentional distractor recognition and to keep the task relevant goal online for correct recognition. In memory Stroop task divided attention is usually achieved by asking participants to engage in a secondary task that is not related with the main recognition task. Secondary task takes up attentional resources from the recognition task efficiently to observe SR effect. A behavioural study has demonstrated that emotional arousal enhances attention to stimuli and leads to more elaborated memory representations (Bradley, Mogg, & Williams, 1994). Therefore, using emotional stimuli in the secondary task would require more attention for the processing of emotional stimuli compared the non-emotional stimuli, leading a bigger gap between the recognition task and the secondary task.

Not only attention but also working memory might be influenced from the emotional processes in two different ways. A bottom up influence of emotion would attract more attention towards emotional information leading to changes in working memory performance. This change might include an enhancement for negative stimuli. Alternatively, a top down approach predicts an influence on the sub-processes of working memory and create an additional load for WM task. The additional load would disrupt executive attention function of working memory.

Aims and Hypotheses

This study aims at investigating the connection between SR and attentional biases, using EWM task to divide the attention of participants. Emotions potentially can create attentional biases. Therefore, to create an additional need for attention negative, positive and neutral stimuli were used in the secondary WM task.

Although previous research lead to different results due to different methodologies, the consensus was always that somehow emotional stimuli influence long term memory, recognition memory and working memory by automatically attracting the attention (Perlstein, et al., 2002; Talmi, 2013; Vuilleumier, 2005). In addition to the attentional requirement that is needed for working memory task, emotionally laden stimuli would take up more attentional resources compared to neutral stimuli. In contrast to intentional and goal-related working memory task with single digit stimuli, with the constrained resources there could be an additional attentional transfer from recognition task to working memory task, and this transfer would be unintentional and automatic with the influence of emotional stimuli. To rephrase, in the previous studies, competition between two tasks have been created, and the secondary working memory task involved neutral stimuli (single digits). However, by using emotional stimuli, we manipulated the attentional balance between two tasks. While working memory task takes away attention in a goal related and voluntary manner, emotions are expected to form attentional bias automatically and involuntarily and thus draw more attention away from the recognition task.

In this study, healthy young participants were recruited. According to socio-emotional selectivity theory, older adults show attentional bias to positive stimuli whereas young adults show attentional bias to negative stimuli (Carstensen & Mikels, 2005; Mikels, Larkin, Reuter-Lorenz, & Carstensen, 2005). Therefore, we hypothesized that any emotional effect on working memory or recognition memory would be more prominent in the negative condition. We hypothesized a greater SR effect with negative emotional working memory task compared to neutral working memory task. Positive EWM might also have a potential to create attentional bias. However, mixed results on the emotional memory literature refrain us from having any strong predictions.

Methods

Participants

Seventy-six healthy young adults, undergraduate students from department of Psychology were recruited from University of Kent. Participants were between 18-33 years old (15 males, M_{age}=19.07, SD_{age}=0.93; 61 females, M_{age}=19.66, SD_{age}=2.47). Health and demographic information was collected prior to the experiment. Two participants were eliminated due to failure in their performance on the secondary WM task (performing less than 50%).

Design

The design of the study was a 2 (target type: old, new) x 2 (distracter type: old, new) x 3 (emotion: neutral, negative and positive) ANOVA, target type, distracter type, and emotion was a within subjects factor. The influence of EWM on SR effect was measured by accuracy (hits and correct rejections) to memory Stroop task. Figure 2.3. shows the schema of the design and representative stimuli.

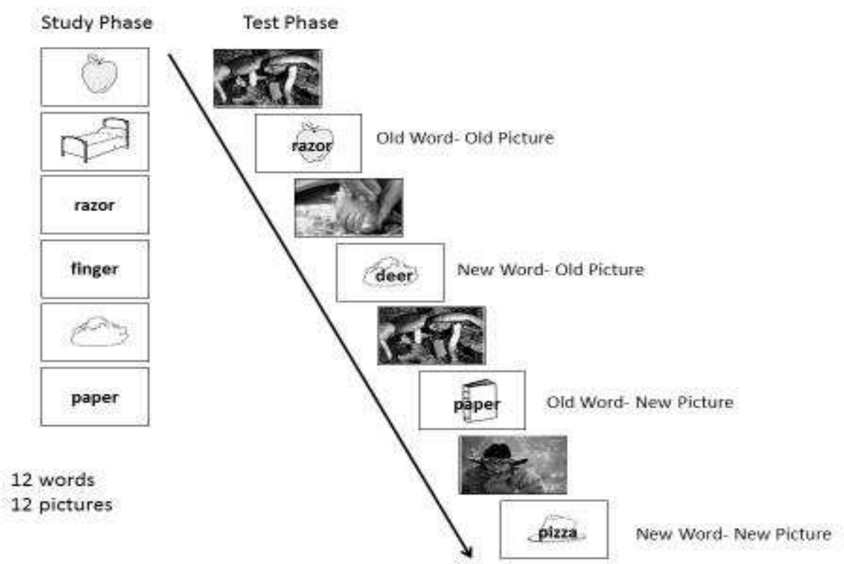


Figure 2.3. Illustration of the experimental procedure in the neutral block

Materials and Procedure

The materials and the procedure were the same with Experiment 1. Though, there were three main differences between experiment 1 and 2. (a) emotional stimuli were used instead of digits. Neutral ($M_{Valence}$= 5.25, $SD_{Valence}$= 0.40; $M_{Arousal}$=4.15 , $SD_{Arousal}$= 0.64) , negative ($M_{Valence}$= 2.41 , $SD_{Valence}$= 0.45; $M_{Arousal}$= 6.33 , $SD_{Arousal}$= 0.32) and positive ($M_{Valence}$= 7.13 , $SD_{Valence}$= 0.54; $M_{Arousal}$= 6.33 , $SD_{Arousal}$= 0.42) pictures were selected from International Affect Picture System IAPS (Lang, Bradley, & Cuthbert, 1997). The difference in valence and arousal between emotional categories were compared with univariate ANOVA. The analysis showed negative, positive and neutral pictures are significantly different in terms of valence ($F (2, 105) = 932.51, p<0.001$), and arousal ($F (2, 105) = 246.10, p<0.001$). Post-Hoc analyses for arousal indicated there was no significant difference of arousal ratings between positive and negative pictures ($t (70) = 0.02, p= 0.99$), arousal ratings of neutral pictures were significantly different from negative ($t (70) = 18.15, p<0.001$) and positive pictures ($t (70) = 17.02, p<0.001$). Post-Hoc analyses for valence indicated there was a significant difference of valence ratings between positive and negative pictures ($t (70) = 40.29, p< 0.001$). Also, valence ratings of neutral pictures were significantly different from negative ($t (70) = 28.29, p<0.001$) and positive pictures ($t (70) = 16.78, p<0.001$). (b) I used only 2-back task as a secondary task in order to load WM with emotional stimuli. (c) Participants completed 3 consecutive rounds for each of the 3 emotion conditions, and this order was counterbalanced across participants. For example, a participant completed 3 consecutive blocks of negative, then positive, and finally neutral making it up to 9 rounds in total.

Results

Analysis of n-back task

We conducted a one-way repeated measures ANOVA with emotion (neutral, negative and positive) as a within subject factor. The dependent variable were accuracy and reaction times in 2-back task. Analysis revealed that working memory accuracy was not significantly different amongst different emotional conditions (F (2, 148) = 1.30, p=0.28, ηp^2=0.02). In contrast, there was a significant difference in reaction times between emotional conditions F (2, 148) = 4.16, p=0.02, ηp^2=0.05. Participants responded significantly slower to negative stimuli (M=1088ms, SD=244) compared to positive (M=1028ms, SD=248ms; t (74) = 2.18, p=0.03), and neutral condition (M=1018ms, SD=222ms; t (74) = 2.86, p=0.006). There was no difference between neutral and positive condition, (t (74) = 0.39, p=0.70).

Analysis on Memory Stroop

A 3 (emotion: neutral, negative and positive) x 2 (target type: old, new) x 2 (distractor type: old, new) repeated measures ANOVA was conducted on accuracy.

Table 2. 5. Means and Standard Deviations of Target Recognition Accuracy

	Old Target		New Target	
	Old Distractor	New Distractor	Old Distractor	New Distractor
Neutral	0.73 (0.20)	0.68 (0.21)	0.82 (0.19)	0.86 (0.16)
Negative	0.67 (0.20)	0.63 (0.21)	0.83 (0.17)	0.86 (0.16)
Positive	0.70 (0.20)	0.68 (0.20)	0.81 (0.18)	0.86 (0.16)

Analysis revealed the non-significant main effect of emotion and distractor type (F (2, 148) = 2.25, p=0.11, ηp^2=0.30, F (1, 74) = 0.22, p=0.64, ηp^2=0.003, respectively). The interaction between emotion and distractor type was also non-significant (F (2, 148) = 1.06, p= 0.35, ηp^2= 0.01).

Furthermore, there was a significant interaction of emotion and target type, (F (2, 148) = 3.65, p=0.03, ηp^2=0.05; see Figure 2.4). Separate paired sample t-tests revealed that there was no difference between neutral, negative and positive conditions in accurate answers to new targets (p>0.57). However, there was a significant difference between neutral (M=0.70, SD= 0.19) and negative (M=0.65, SD=0.19) condition (t (74) = 3.00, p=0.004) and between negative and positive (M=0.69, SD=0.18) condition (t (74) = 6.60, p<0.001). But there was no difference between neutral and positive condition (t (74) = 1.01, p=0.32).

Table 2. 6. ANOVA results for Memory Stroop recognition accuracy

Source	F	p	ηp^2
E	2.25	0.11	0.03
T	**38.19**	**<0.001**	**0.34**
D	0.22	0.64	0.003
E * T	**3.65**	**0.03**	**0.05**
E * D	1.06	0.35	0.01
T * D	**22.97**	**<0.001**	**0.24**
E * T * D	0.34	0.72	0.005

T=Target, D=Distractor, E=Emotion, *p<0.05, **p<0.001

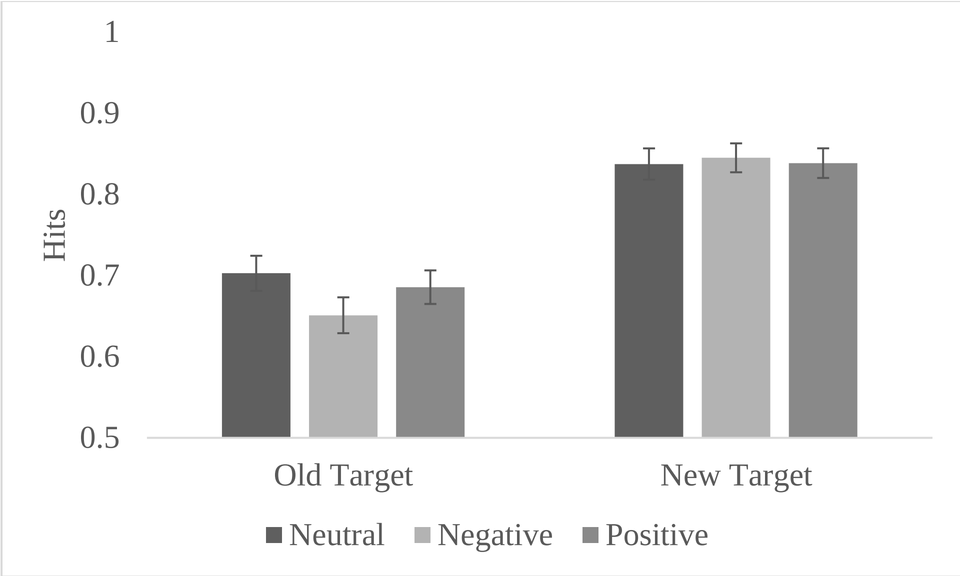


Figure 2.4. Mean correct response accuracy of old (left) and new (right) targets for neutral (grey bar), negative (red bar), and positive (blue bar). Error bars represent the standard error of the mean.

Importantly, there was a significant interaction of target and distractor. Participants were more accurate when old target was paired with old distractor (M=0.70, SD=0.16) compared to new distractor (M=0.66, SD=0.18; t (74) = 3.51, p=0.001) and when new target was paired with new distractor (M=0.86, SD=0.14) compared to old (M=0.81, SD=0.16; t (74) = 4.22, p<0.001; see Figure 2.5).

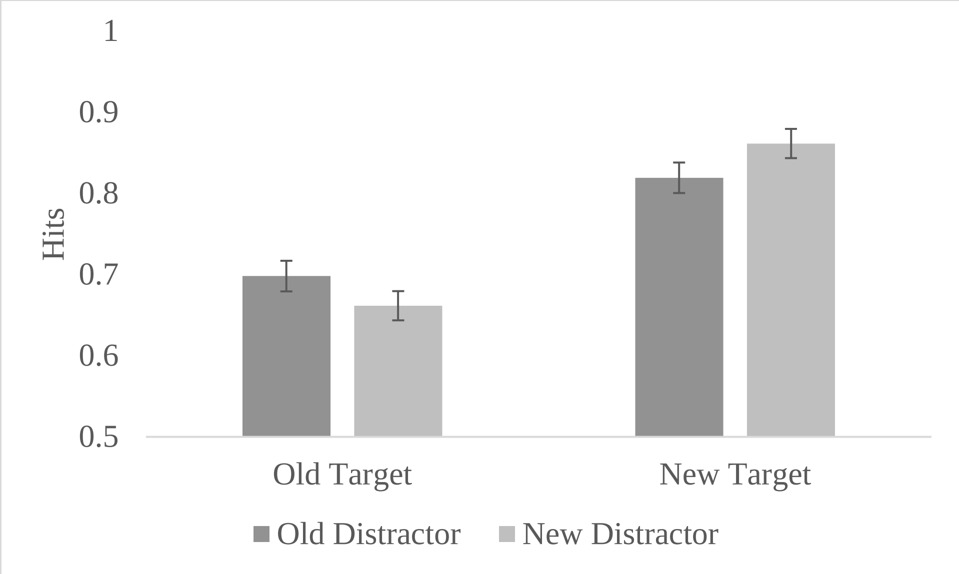


Figure 2.5. Mean correct response accuracy of old (left) and new (right) targets for old distractor (dark grey bar), and new distractor (light grey bar). Error bars represent the standard error of the mean.

Finally, there was no three-way interaction of emotion, target and distractor (F (2, 148) = 0.34, p=0.71, ηp^2=0.005). This revealed that target and distractor relationship was not modulated by emotion.

Discussion

This experiment aimed to investigate whether dividing attention with emotional information would have an additional effect on SR effect. It has been well-established that negative information is remembered better than neutral information (Kensinger & Corkin, 2003b) and is often unintentional (Talmi, 2013). The unintentional biasing of attention toward emotional information could result in enhanced processing of the distractor. Therefore, we hypothesized that a WM task presented with emotional stimuli would use more attentional resources than non-emotional (neutral) stimuli in a dual task paradigm. Thus, this may result in having less resources for Memory Stroop task and participants would show the SR effect on emotional condition than non-emotional condition.

Results on WM task revealed that participants were equally accurate in different emotional conditions however they were slower to respond to negative pictures compared to neutral and positive ones. This finding indicates that greater attentional resources were used to complete the WM task with negative stimuli. The slowing effect with negative stimuli was in accordance with socio-emotional selectivity theory which argues that young adults generally show attentional bias to negative stimuli (Carstensen & Mikels, 2005). Further, slower responses might indicate the interference of emotional processing of negative stimuli on working memory. Kensinger and Corkin (2003b) argued that processing of emotional stimuli might interfere with task-related WM processes. Results of EWM task implies that negative stimuli created further attentional bias, but only for target recognition. Additionally, our experiment consisted of two tasks and participants were not instructed to prioritize one task over another. Therefore, having divided attention between tasks may have constrained the overall processing capacity and leading emotional information to consume more resources only on working memory task. Accordingly, structural equation modelling analysis supports that constrained processing enables emotional stimuli to grab larger resources compared to neutral stimuli (Talmi & McGarry, 2012).

Results from the memory Stroop task yielded three important findings. Firstly, we replicated previous findings in demonstrating SR using the Memory Stroop task (Anderson, et al., 2011; Bergström, et al., 2016). Secondly, we showed that in a dual task paradigm a secondary task that included emotions may affect only target recognition judgements. This finding is in line with the mediation model which acknowledges immediate effects of emotions (Talmi, 2013). We found that participants were less accurate for old target recognition on negative condition than neutral and positive condition but emotion did not influenced recognition of the new targets. A previous report also found better recognition for negative old words than neutral old words (Windmann & Kutas, 2001). Corrected recognition scores (hits-false alarms) also indicated better remember responses (indicator of recollection) of negative than neutral stimuli (Kensinger & Corkin, 2003b). Also, the negative emotions take up more WM resources for attentional control, and away from memory storage (Schweizer & Dalgleish, 2016), as a result, old targets were more affected by emotions than new stimuli. To sum, lack of interaction of emotional condition of the secondary task and SR effect suggest that the emotional stimuli might not be strong enough to affect the unintentional recognition of distractors on intentional target recognition.

Chapter 3

Unintentional recognition: Underlying neural mechanisms and the role of working memory.

Previous chapters presented the evidence that unintentional recognition of distractors could affect recognition of target items when they were presented in the same context, and especially when working memory was loaded with another task simultaneously. This finding is consistent with previous research, which revealed that dividing attention with a secondary task enhances the effect of unintentional recognition on target recognition in young adults (Anderson, et al., 2011; Ste-Marie & Jacoby, 1993). The finding that the old/new status of distractors had a biasing effect on target recognition was later replicated by (Bergström, et al., 2016). Specifically, they found that old distractors increased the likelihood that old target words would be correctly recognized compared with new distractors. This research also revealed a dissociation between the ERP markers of familiarity (FN400) which was found for old distractors and old targets, and the ERP marker of recollection (parietal old/new effects, (parietal old/new effects, Rugg & Curran, 2007) which was found only for old target items. Instead, old distractors were associated with a late negative posterior slow drift, which was interpreted as related to post-retrieval monitoring. The results thus suggested that unintentional and intentional recognition were mediated by different episodic retrieval processes.

The functional connection between WM and selective attention is argued to stem from the central executive component of WM, which aids selective attention to target information, especially when faced with distraction (Repovš & Baddeley, 2006). Furthermore, de Fockert et al. (2001) provided evidence for the causal role of

WM in the control of selective attention with an fMRI study. They hypothesised that introducing additional load on WM should interfere with the selective processing of task-related items. They hypothesised that introducing an additional load on WM should interfere with the selective processing of task-related items. To test, participants were asked to classify famous written names as pop stars or politicians while ignoring distractor faces. The distractor faces were equally likely to be congruent with the target name, incongruent with the target name, or anonymous. The selective attention task was conducted simultaneously with a secondary WM task (either with low or high WM load). Reaction times indicated slower responses/larger distractor interference during high (78ms) than low (46ms) working memory load, indicating more distractor processing when working memory has a high load. They also found enhanced activation for distractors in face processing related brain areas (i.e., bilateral fusiform gyri, right inferior occipital lobe, and left lingual gyrus) and increased activity of prefrontal cortex under conditions of high WM load compared to low. These behavioural and fMRI results thus confirm an interaction between WM and selective attention and suggest that the availability of WM is necessary for top-down attentional control.

The role of WM in distractor processing is not limited to attention control. The dual mechanisms of control framework (DMC) propose two distinct control processes; proactive and reactive control (Braver, 2012). According to this framework, proactive control can be considered as an early selection mechanism that maintains the task-relevant information to modulate the cognitive processes such as attention, perception and preparation of responses whereas reactive control works as a late selection mechanism that automatically directs attention to task-relevant stimuli in the presence of an interference situation. Specifically, WM supports processing of task-relevant information by using its ability to alter responses to task demands instead of automatic responses (Brewer & Sampaio, 2006).

Although, a successful cognition requires both control mechanism, there is likely to be some bias for one type of control strategy over the other. In this study, participants may be biased to adopt a proactive control mechanism when expected load is low, allowing spare working memory resources to be allocated to prepare for the upcoming test probe. By contrast, expected high load may bias them to use probe as a retrieval cue which activates reactive control. Also, if participants engage in early selective attention processes, then their proactive control would be activated. By contrast, if they engage late mechanisms then their reactive control would be triggered.

To further illustrate, in memory Stroop task, there were two different inputs coming from picture and word. As a result of reactive control, picture and word stimuli triggers a bottom-up recognition response individually. Although pictures trigger stronger response for recognition (because it is more salient than words), proactive control makes sure that word recognition is prioritised to satisfy the task needs. This is the top-down control of unintentional picture recognition by proactive control. Since working memory provides resources for proactive control, a loaded WM would be less available to maintain task demands. Thus, shortness of resources may cause less control over task demands and instead, may engage in bottom-up picture recognition. As an alternative solution in the situation of the insufficiency of proactive control, participants may engage in reactive control automatically. To test whether participants use their proactive control, reactive control or both EEG was also employed to provide temporal information on the possible control mechanisms.

The main aim of this study was to examine the role of WM in how unintentional distractor recognition influences intentional target recognition as assessed with neural markers. Primarily, a replication and extension on Bergström et al.'s (2016) ERP study was aimed, which did not include a WM manipulation and was therefore not able to investigate this issue. Therefore, a very similar experiment was conducted, with the addition that WM load was manipulated with a secondary task between blocks, using the load manipulation from (de Fockert, et al., 2001). Behaviourally, a replication of a biasing influence of distractors on target recognition accuracy was anticipated. Based on (Bergström, et al., 2016) it was also expected that neural results would indicate ERP signs of familiarity in the FN400 for both old targets and old distractors, but that evidence of recollection across the left parietal sites would be found only for old targets. Furthermore, an enhanced negative slow drift monitoring effects for old distractors were expected. When the secondary task involved high WM load, it was expected to decrease the availability of WM, and in turn the control of attention to intentional recognition targets. Such depletion of WM resources should result in increased task-irrelevant processing of distractors which should enhance distractor influences on target recognition. Additionally, participants may show a preference on employing a reactive control when there is a conflict of target and distractor recognition or a proactive control throughout the experiment to satisfy the dual task needs. The latter control mechanism would predict a larger difference in SR effect for high than low WM load conditions as proactive control require WM resources. In contrast, a reactive control would emerge in a bottom up manner when a conflict was detected.

Methods

Participants:

Thirty-six right-handed, neurologically normal native English speakers participated. Participants received course credit or were given money for their participation. Five participants were eliminated from analyses, due to excessively noisy EEG recordings, and the final sample was made up of 31 participants (M_{age} = 20.26 years, range = 18-25 years, 14 males and 17 female). All participants gave written informed consent, and the experiment was approved by the University of Kent Psychology Research Ethics Committee.

Materials:

Target words (target) and distractor pictures were taken from (Bergström, et al., 2016) study. Their stimuli were consisted of 336 words and 336 colour photographs of objects, events and scenes. Words were taken from the ANEW database and their valence ratings ranged from 3.79 to 7.58 on a 9-point scale (ranged from 4 to 8 letters and no more than two syllables). From the 336 picture stimuli, 277 were taken from the IAPS database (Lang, Bradley, & Cuthbert, 2008) and their valence ratings ranged from 1.51 to 6.62 on a 9-point scale, and 43 were taken from the GAPED database (Dan-Glauser & Scherer, 2011) with valence ratings ranged from 1.35 to 45.7 on a 100-point scale. Sixteen stimuli of each type (word and picture) were used in a practice phase and the remaining 320 were used in the experiment. Assignment of words and pictures to experimental conditions was fully counter-balanced across participants. (Bergström, et al., 2016) used negative and neutral pictures to measure the effects of emotional valence of distractors on target recognition but failed to find an effect of valence on behavioural and neural measurements. We replicated their finding that the emotional valence of distractors did not affect target or distractor recognition. Hence, we combined all measurements across emotional factors.

Design and procedure:

The design of the study was based on the “memory Stroop” paradigm developed by (Anderson, et al., 2011) and modified by (Bergström, et al., 2016). After giving informed consent, participants were instructed and completed a practise task, then moved on to the experiment which consisted of 10 study-test rounds. In study phase, participants were asked to rate the pleasantness of 16 words and 16 pictures (randomly presented) on a scale between 1 and 4 (1-very unpleasant and 4-very pleasant) by pressing the number keys on the keyboard. They were told that their memory for all items would later be tested. Stimuli were presented at the center of the screen for 3000ms and preceded by 500ms fixation cross. In the Memory Stroop test phase, 32 pairs of words superimposed on pictures were presented, and participants were asked to ignore the pictures and make a recognition judgement on each word (to indicate whether they saw the word in study phase), with response hand counterbalanced across participants. Each test block was made up of an equal number of the four target/distractor item types: old word and old picture (eight trials), old word and new picture (eight trials), new word and old picture (eight trials), and new word and new picture (eight trials), randomly displayed. Pairs were presented for 3000ms, preceded by a 500ms fixation cross.

In addition to the Memory Stroop task participants were required to complete a WM task simultaneously. The WM task required participants to rehearse digit sequences, which have been shown to create interference from distractor processing in other tasks when the digit strings are random and repeatedly changing (e.g., de Fockert, et al., 2001). In the high WM load blocks, randomly ordered five-digit sequences (0–4, always beginning with 0 but with 1–4 in random order) were shown for 3000ms, and participants were required to rehearse the sequence of numbers while completing the Memory Stroop task simultaneously. After four to six trials, a single digit probe was displayed for 3000ms, and participants were asked to indicate the number from the keyboard corresponding to the next digit in the number sequence that they were currently rehearsing. Visual feedback (either "incorrect", "correct", or "no response") was provided to encourage participants to pay attention to WM task sufficiently. After the probe, participants were shown a new number sequence to rehearse in the following four to six recognition trials until the next probe. In the low WM load blocks, the digit sequence was always "01234" and participants were told that they should not rehearse the digit sequence because the correct answer to the probe was always predictable (i.e. the next larger integer). Half of participants completed five high WM blocks followed by five low WM blocks, and the other half completed the WM blocks in the reverse order.

In the Memory Stroop task, target words were always tested whereas distractor pictures were always ignored. Therefore, it was necessary to emphasize study processing of the pictures as well as targets, to ensure that participants did not try to prevent encoding of the pictures. To solve this issue, after each test phase, participants were given a distractor recognition test consisting of two previously seen distractors intermixed with two novel pictures and were asked to press one button to classify whether distractors as "old" (previously seen) or "new" (not seen at any point in the experiment). Figure 3.1 shows the schema of the design and representative stimuli.

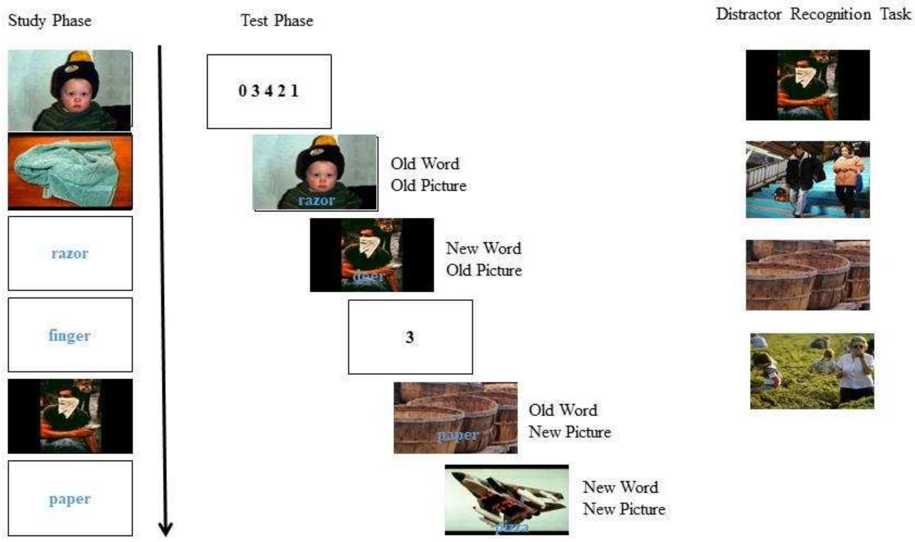


Figure 3. 1. Illustration of the experimental procedure.

EEG Recording and Analysis:

EEG was recorded at 500 Hz with a 0.05- to 70-Hz bandwidth. The recording reference electrode was set to FCz and 64 scalp electrodes were placed in an actiCAP according to the extended 10–20 system (Brain Products GmbH, München, Germany). Eye movements were recorded from below the left eye (vertical EOG) and from the right outer canthi (horizontal EOG). Continuous EEG data from all channels were imported into EEGLAB and were analysed using EEGLAB (UC San Diego; Delorme & Makeig, 2004). The EEG was re-referenced to the average of the mastoids and epoched using a 200ms pre-stimulus baseline period and a 3000ms post-stimulus period, that was time-locked to the onset of the word–picture pair in the test phase. After concatenating epochs, large artefacts due to subject’s motion, facial movements, or other irregularities that may distort ERPs were manually eliminated. Epochs were submitted to independent component analysis using RunICA from the EEGLAB toolbox, with default extended-mode training parameters (Delorme & Makeig, 2004). Independent components reflecting eye movements and other sources of noise were identified by visual inspection of component scalp topographies, time courses, and activation spectra and were discarded from the data by back-projecting all but these components to the data space. Corrected data were subsequently high-pass filtered digitally at 30 Hz. Finally, any trials that still contained artefacts after filtering were removed based on visual inspection. Only a very small percentage of trials (5%) were deleted in total. Final ERPs were formed for the eight conditions: old word old picture low WM (mean trial numbers =36.5) old word old picture high WM (mean trial numbers =37.3) old word new picture low WM (mean trial numbers =36.1), old word new picture high WM (mean trial numbers =37.2), new word old picture low WM (mean trial numbers =36.3), new word old picture high WM (mean trial numbers =37.1), new word new picture low WM (mean trial numbers =36.5), and new word new picture high WM (mean trial numbers =37.3).

For statistical analysis, time windows and electrode locations were chosen based on Bergstrom et al. (2016) to measure the early frontal and later parietal old/new effects corresponding to familiarity and recollection-based retrieval processing, as well as the late posterior negative (LPN) ERP slow drifts that are thought to index retrieval monitoring processes. The early FN400 old/new effects was measured as the mean amplitude between 300 to 500ms at the mid-frontal (Fz) electrode, and the later parietal old/new effect was measured as the mean amplitude between 500 to 800ms at the left parietal (P3) electrode. The LPN was measured as the mean amplitude at left (PO7) and right (PO8) parieto-occipital electrodes between 500 to 1000ms, which is where and when the LPN effect in Bergström et al. (2016) was maximal. The mean amplitudes for time windows were extracted and statistically analysed in IBM SPSS Statistics for Windows (Version 22.0, IBM Corp., Armonk, NY, USA).

Results

Behaviour:

Analysis of WM task

Accuracy in high WM load condition varied from 100% to 71% whereas it ranged from 100% to 91% in low WM load condition. For the WM task performance, accuracy and reaction time measurements of low load and high load were compared with paired samples t-test. Analysis revealed that there was a significant difference between low load and high load in accuracy and reaction times, (t (30) = -5.48, $p <$ 0.001; t (30) = 12.04, $p < 0.001$), respectively. Participants were more accurate in WM task in low load (M=0.96, SD=0.03) compared to high load (M=0.84, SD=0.12) condition. Moreover, participants were slower to respond in high load (M=1629, SD=216) compared to low load (M=1238, SD=198) condition. These differences between low and high WM load conditions thus confirmed that the manipulation of WM load had been successfully implemented and ruled out a speed-accuracy trade-off (see Figure 3.2).

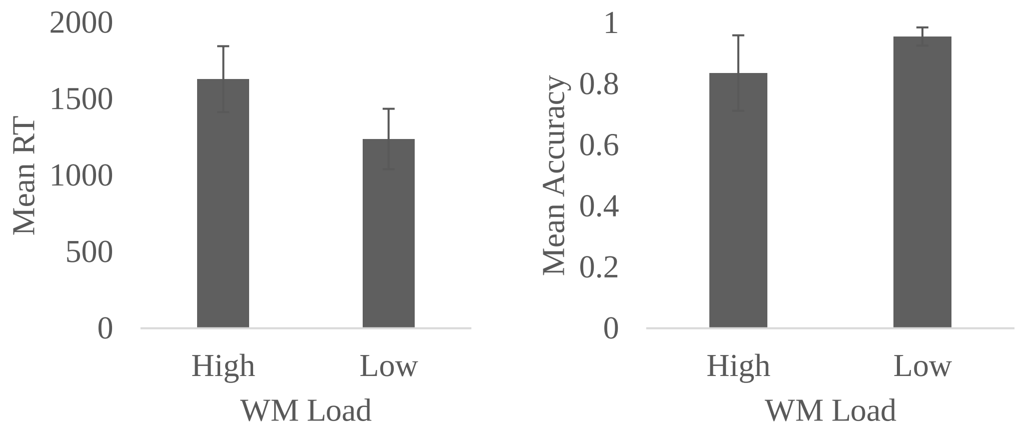


Figure 3. 2. Means and standard deviations of accuracy (right graph) and RT (left graph) for High and Low WM Conditions.

Analysis of Memory Stroop task

For the Memory Stroop task, accuracy was analysed with a 2 (target type: old, new) x 2 (distracter type: old, new) x 2 (working memory load: high, low) repeated measures ANOVA (see Table 3.1.). Mean accuracy and standard deviations are presented in Table 3.2.

Table 3. 1. Mean hit and correct rejection scores and standard deviations for target type, and distractor type for high and low WM load conditions.

Source	F	Sig.	Partial Eta Squared
T	0.05	0.83	0.002
D	3.84	0.06	0.12
WM	0.10	0.75	0.003
T * D	**4.75**	**0.04***	**0.14**
T * WM	2.77	0.11	0.09
D * WM	2.19	0.15	0.07
T * D * WM	0.12	0.73	0.004

D=Distractor, WM= Working Memory Load, *p<0.05, **p<0.001

The analysis revealed non-significant main effects of the target type and distractor type factors. Furthermore, no significant main effect was found between the WM load conditions for accuracy, indicating that participants were not differentially engaged in the memory Stroop task in the different WM conditions. However, a significant interaction effect between target and distractor type (F (1, 29) = 4.75, p=0.04, ηp^2=0.14) was found. Participants were more accurate when old targets were paired with old distractors and new targets were paired with new distractors. Accuracy was higher for new target and new distractor pairs compared to new target and old distractor pairs (t (29) = 2.77, p=0.01). The difference between old target old distractor pairs and old target new distractor pairs did not differ significantly (t (29) = 0.71, p= 0.48). However numerically, participants were more accurate in old target old distractor pairs than in old target new distractor pairings (see Table 3.1). The interaction of target and WM load, distractor and WM load, and finally three-way interaction of target, distractor and WM load were non-significant ($F(1, 29) = 2.77$, $p=0.11$, $\eta p^2=0.09$; $F(1, 29) = 2.19$, $p=0.15$, $\eta p^2=0.07$; $F(1, 29) = 0.12$, $p=0.73$, $\eta p^2=0.004$, respectively).

Table 3. 2. Mean hit and correct rejection scores and standard deviations for target type, and distractor type for high and low WM load conditions.

	Mean (SD)	
	High WM Load	Low WM Load
Old Target Old Distractor	0.88 (0.15)	0.88 (0.11)
Old Target New Distractor	0.88 (0.15)	0.85 (0.16)
New Target Old Distractor	0.86 (0.14)	0.87 (0.13)
New Target New Distractor	0.90 (0.10)	0.90 (0.10)

Analysis of Discrimination and Response Bias

Response bias and discriminability are two measures produced from recognition memory tasks that are beneficial in understanding the cognitive processes. According to signal detection theory, old–new recognition decisions can be affected by response bias, a general tendency to respond either “old” or “new.” Response bias reflects the processes underlying the making a decision between two options, whereas discrimination refers to the accuracy that reflects the memory strength. Therefore, as an additional analysis, I calculated estimates of discrimination (Pr) and response bias (Br) (see Snodgrass & Corwin, 1988). This was done to investigate whether unintentional recognition of distractors primarily affected response biases or also the ability to discriminate between old vs. new targets (see Table 3.2). Response bias reflects the tendency to either respond in a liberal (i.e., "yes") or conservative (i.e., "no") direction. Values of Br that are above 0.5 indicate a tendency to guess "old" rather than "new" when uncertain, (a positive response bias), whereas values below 0.5 indicate the opposite tendency (a negative response bias). The Br is calculated by dividing each participant's false alarm rate by 1 – Pr. The Pr reflects the discrimination between old and new items that is corrected for response biases and to calculate, new word false alarms were subtracted from old word hits separately based on distractor type (old and new).

Table 3. 3. Means and Standard Deviations of Discrimination Performance (Pr) and Response Bias (Br) for Target Recognition Decisions

	High WM Load		Low WM Load	
	Mean (SD) Br	Mean (SD) Pr	Mean (SD) Br	Mean (SD) Pr
Old Distractor	0.57 (0.28)	0.76 (0.20)	0.53 (0.26)	0.77 (0.17)
New Distractor	0.49 (0.24)	0.79 (0.17)	0.44 (0.30)	0.78 (0.17)

Two-way ANOVAs conducted with the factors distractor (old vs. new) and WM load (high vs. low) on Pr and Br. The analysis revealed a marginally significant main effect of distractor, and non-significant main effect of WM load as well as the interaction between distractor type and WM load on Pr and Br (see Table 3.3 for details). Participants discriminated words paired with new distractors (M=0.79, SD=0.16) better than old distractors (M=0.77, SD=0.18). Moreover, they showed positive response bias to words paired with old distractors (M=0.55, SD=0.24) and a negative response bias to words paired with new distractors (M=0.47, SD=0.25).

Table 3. 4. ANOVA results for Response Bias (Br) and Discrimination (Pr)

Pr	F (1, 29)	p	ηp^2
D	3.84	0.06	0.12
WM	0.10	0.75	0.003
D x WM	2.19	0.15	0.07
Br			
D	3.90	0.06	0.13
WM	1.31	0.26	0.05
D x WM	0.02	0.88	0.001

D=Distractor, WM= Working Memory Load, *p<0.05, **p<0.001

Analysis of Correlation between SR effect and WM Performance

I did Spearman’s correlations to observe whether WM task accuracy (performance) correlated with the size of the congruency accuracy effect (congruent minus incongruent conditions) on the Memory Stroop task. Results indicated positive (but non-significant) correlations in both high (r_s=0.33, p=0.08) and low WM load conditions (r_s=0.31, p=0.10). The results indicated that there was a weak positive relationship between WM performance and the congruency accuracy effect.

ERPs:

FN400 Old/New Effects

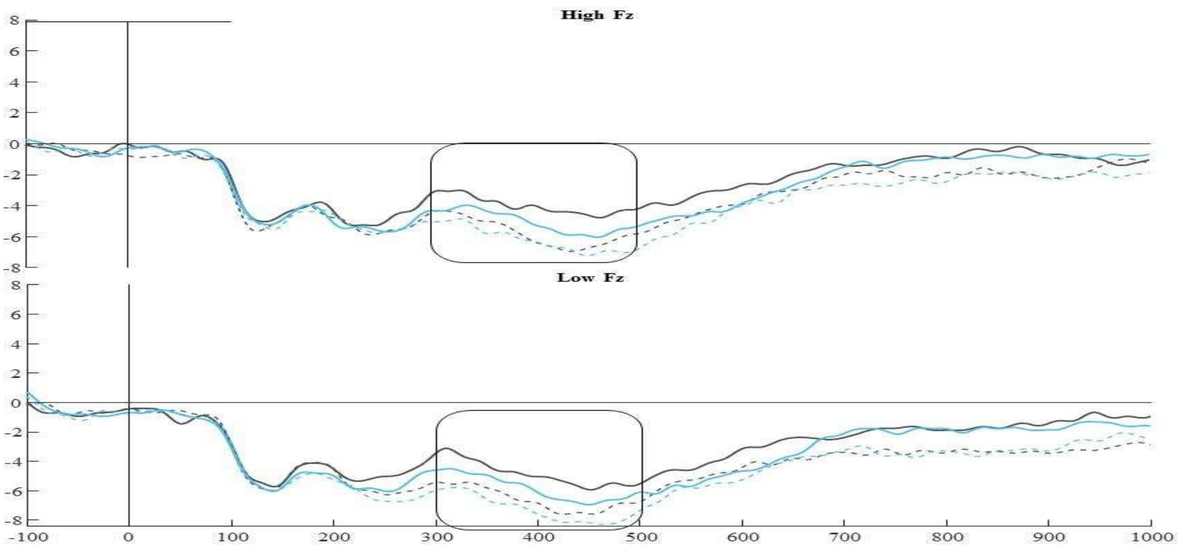
Grand-averaged ERPs from the mid-frontal (Fz) site for high and low working memory loads are displayed in Figure 3.3. Both old targets ($F(1, 29) = 10.53$, $p=0.003$) and old distractors ($F(1, 29) = 34.61$, $p<0.001$) elicited significantly more positive FN400 amplitudes than new targets and new distractors, respectively, replicating previous findings (Bergström, et al., 2016). In addition, there was a significant main effect of WM load, FN400 was more positive in low WM load trials compared to high WM load trials ($F(1, 29) = 8.42$, $p=0.007$), irrespective of old/new status of the words or pictures, as none of the interactions were significant (see Table 3.4).

Table 3. 5. ANOVA results for FN400 ERP effects

Source	F (1,29)	p	ηp^2
T	**10.53**	**0.003***	**0.27**
D	**34.61**	**<0.001****	**0.54**
WM	**8.42**	**0.007***	**0.23**
T x D	1.56	0.22	0.05
T x WM	0.09	0.77	0.003
D x WM	0.07	0.79	0.002
T x D x WM	0.11	0.75	0.004

T=Target, D=Distractor, WM= Working Memory Load, *p<0.05, **p<0.001

(A)



(B)

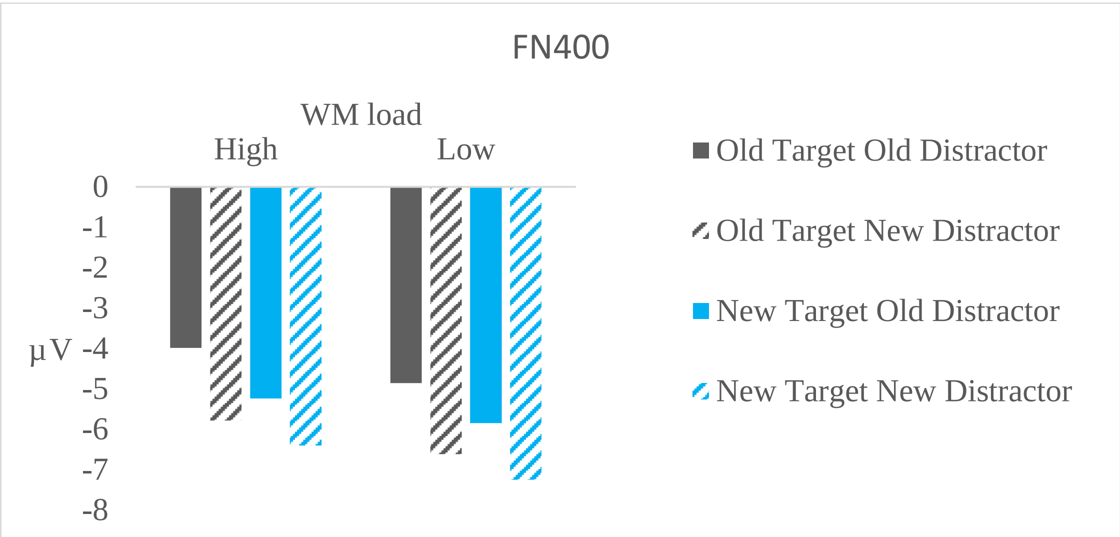


Figure 3. 3 (A) Grand-average ERPs showing FN400 old/new effects for targets and distractors. The box illustrates the 300-500ms time-window used for statistical analysis. ERPs from mid-frontal (Fz) site in high (upper panel) and low (lower panel) WM load conditions. (B) Mean FN400 amplitudes between 300-500ms for the different target and distractor types separated for low and high WM load conditions.

Parietal Old/ New Effects

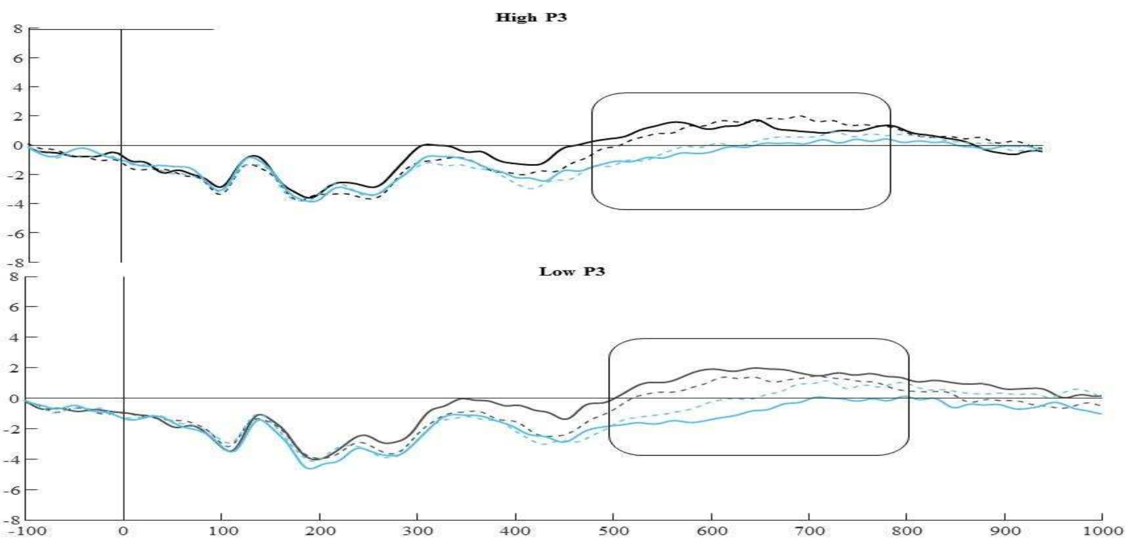
Grand-averaged ERPs from the left parietal (P3) electrode sites for high and low working memory loads are displayed in Figure 3.4. In contrast to the FN400, a typical increased parietal positivity for old compared with new items was only found for word targets, $F(1, 29) = 31.87$, $p < 0.001$, $\eta p^2=0.52$, but not for picture distractors ($F(1, 29) = 0.72$, $p = 0.40$, $\eta p^2=0.02$) again replicating previous findings (Bergström, et al., 2016). There was no significant effect of WM load on the parietal old/new effect, and no interactions (see Table 3.5).

Table 3. 6. ANOVA results for LPC ERP effects

Source	F (1, 29)	p	ηp^2
T	**31.87**	**<0.001****	**0.52**
D	0.72	0.40	0.02
WM	0.002	0.97	<0.001
T x D	3.15	0.09	0.10
T x WM	0.32	0.57	0.01
D x WM	0.002	0.97	<0.001
T x D x WM	1.60	0.22	0.05

T=Target, D=Distractor, WM= Working Memory Load, *p<0.05, **p<0.001

(A)



(B)

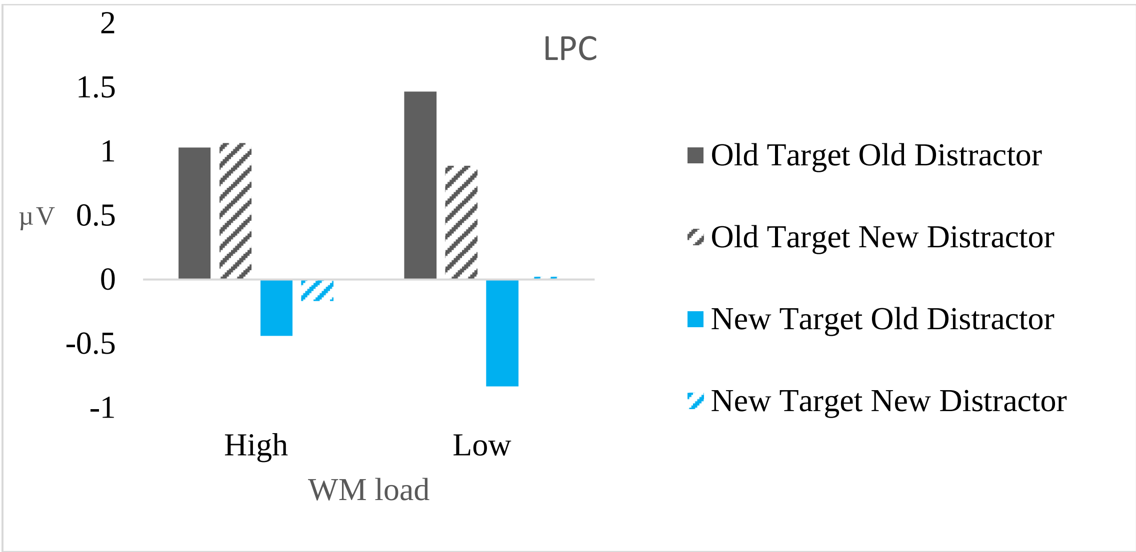
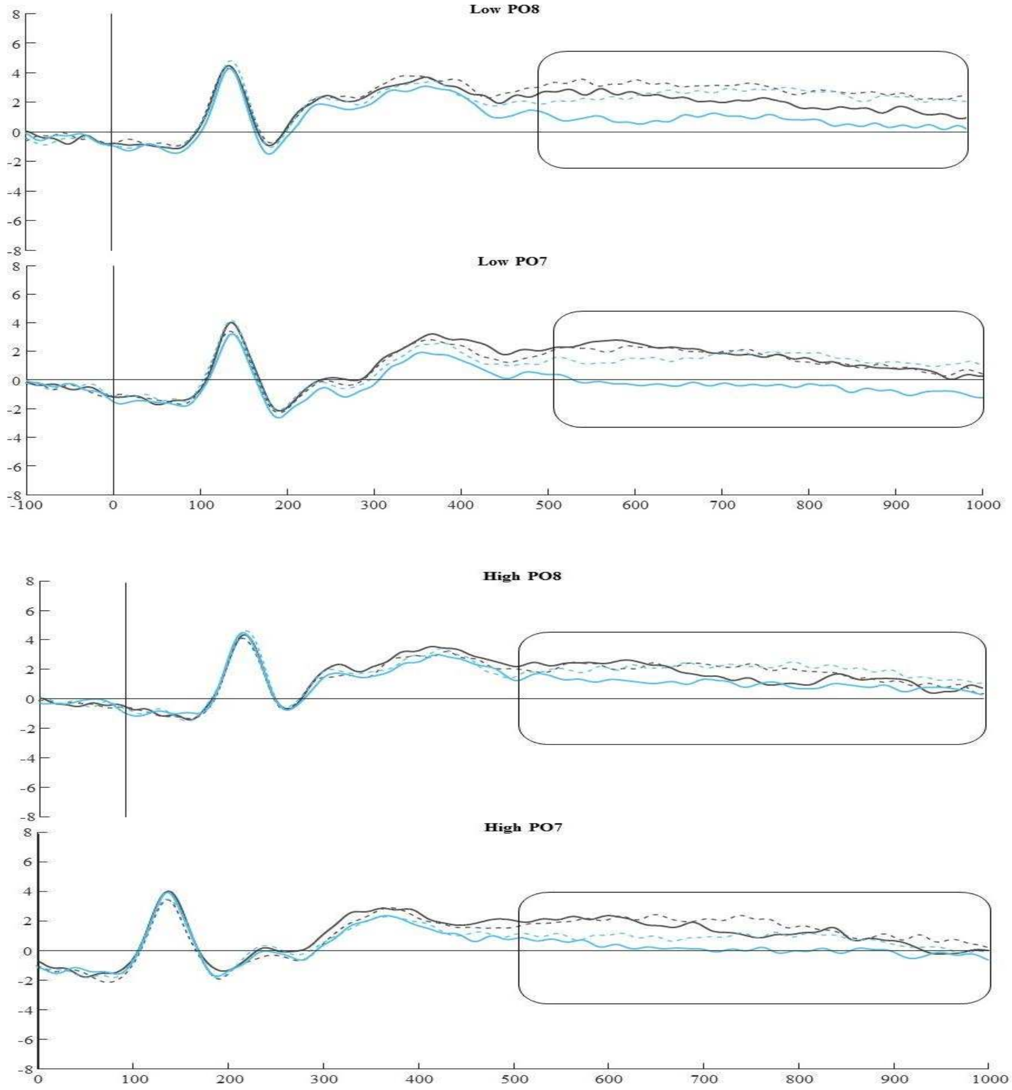


Figure 3. 4. (A) Grand-average ERPs showing left parietal old/new effects for targets and distractors. The box illustrates the 500-800ms time-window used for statistical analysis. ERPs from the left parietal (P3) site in high (upper panel) and low (lower panel) WM load conditions. (B) Mean left parietal amplitudes between 500-800ms for the different target and distractor types separated for low and high WM load conditions.

The Late Parietal Negativity

Grand-averaged ERPs from the left (PO7) and right (PO8) parieto-occipital electrode sites for high and low working memory loads are displayed in Figure 3.5. The LPN was analysed with a 4-way repeated measures ANOVA, with the factors hemisphere (left PO7/right PO8) x target type (old/new) x distractor type (old/new) x WM load (high/low). This analysis revealed (Table 3.5) that there was a significant main effect of target type ($F(1, 29) = 13.64$, $p=0.001$, $\eta p^2=0.32$) and a main effect of distractor type ($F(1, 29) = 24.59$, $p<0.001$, $\eta p^2=0.46$). Participants showed more negativity to new targets (M=1.01, SD=2.17) compared to old targets (M=1.77, SD=2.15), and they showed more negativity to old distractors (M=0.96, SD=2.07) compared to new distractors (M=1.81, SD=2.21). Also, there was an interaction between target and distractor type ($F(1, 29) = 6.35$, $p=0.02$, $\eta p^2=0.18$). Paired samples t-tests were conducted to explore the interaction. The LPN was marginally more negative for old target old distractor pairings than old target new distractor pairings ($t(29) = 1.92$, $p=0.07$). On the other hand, the LPN was significantly more negative in new target old distractor pairings than the new target new distractor pairings ($t(29) = 4.22$, $p<0.001$). Interestingly, target interacted with hemisphere, ($F(1, 29) = 6.05$, $p=0.02$, $\eta p^2=0.17$). The LPN was more negative in the left than right hemisphere for the new targets, ($t(29) = 2.42$, $p=0.02$) whereas there was no difference observed between left and right hemisphere for the old targets, ($t(29) = 1.24$, $p=0.23$). Moreover, there was a significant interaction between hemisphere and WM load, ($F(1, 29) = 4.58$, $p=0.04$, $\eta p^2=0.14$). More negativity was observed in left than right hemisphere for low WM load condition, ($t(29) = 2.35$, $p=0.03$), whereas there was no difference observed between left and right hemisphere in high WM load condition, (t (29) = 1.34, p=0.20).

(A)



(B)

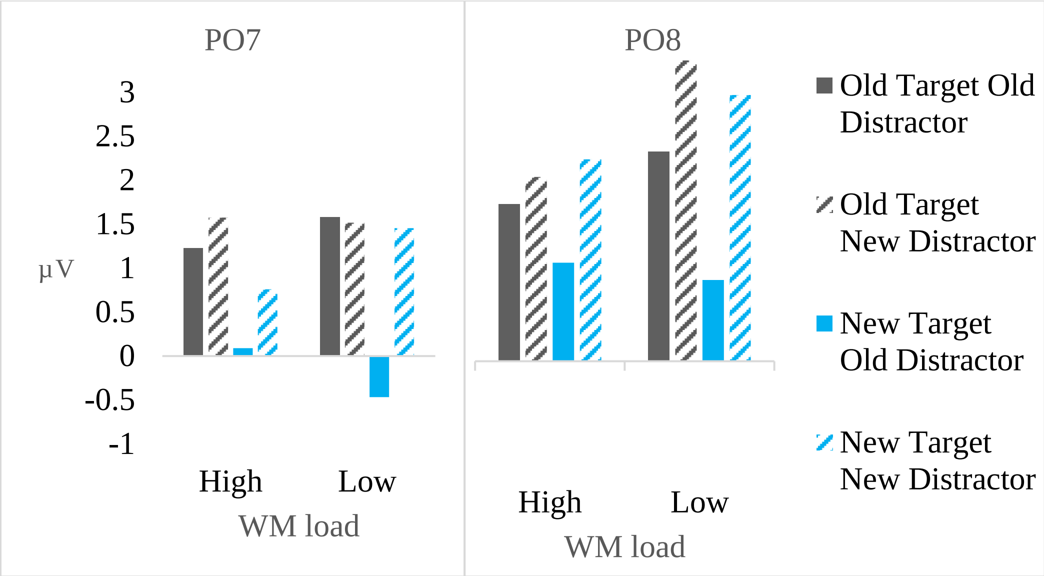


Figure 3. 5 (A) Grand-average ERPs of old/new effects for targets and distractors. ERPs from left posterior (PO7, lower panel) and right posterior (PO8, upper panel) sites in high (right column) and low (left column) WM load conditions. (B) Mean P07 (left) and PO8 (right) amplitudes for hit and correct recognition responses separate for low and high WM load conditions.

Table 3. 7. ANOVA results for LPN ERP effect

Source	F (1, 29)	p	ηp^2
HEM	3.50	0.07	0.11
T	**13.64**	**0.001****	**0.32**
D	**24.59**	**<0.001****	**0.46**
WM	1.21	0.28	0.04
HEM X T	**6.05**	**0.02***	**0.17**
HEM X D	1.17	0.29	0.04
T X D	**6.35**	**0.02***	**0.18**
HEM X T X D	0.56	0.46	0.02
HEM X WM	**4.58**	**0.04***	**0.14**
T X WM	0.98	0.33	0.03
HEM X T X WM	1.81	0.19	0.06
D X WM	2.15	0.15	0.07
HEM X D X WM	0.60	0.45	0.02
T X D X WM	1.87	0.18	0.06
HEM X T X D X WM	3.49	0.07	0.11

T= Target, D=Distractor, WM= Working Memory Load, HEM= Hemisphere,

*p<0.05, **p<0.001

Results summary

In sum the key behavioural and ERP findings were: (a) a significant interaction between target and distractor type for intentional recognition accuracy showed that participants performed better on the recognition task when the target and distractor pairings were congruent vs. when they were incongruent. (b) The ERP results showed that both targets and distractors elicited the FN400 correlate of familiarity, whereas the left parietal correlate of recollection was only present for targets. (c) Although we failed to find an effect of WM load on behavioural measurements, ERPs indicated that frontal ERPs in the FN400 time-window was more positive in the high WM condition compared to low WM condition, confirming that the WM load manipulation influenced neural processing on the memory Stroop task. (d) previous findings were replicated that old distractors triggered retrieval monitoring as indexed by enhanced LPN effects. (e) Extending previous research, the LPN was found to be more pronounced specifically when old distractors were paired with new targets, and (f) the LPN was larger across the left hemisphere for low WM load whereas it was more bilateral in the high WM load condition, suggesting differences in retieval monitoring as a function of WM load.

Discussion

This study aimed to determine how WM availability influences unintentional recognition of distractors and intentional recognition of targets by manipulating WM load and measuring the neurocognitive markers of distractor and target recognition. As predicted, the behavioural results replicated previous research investigating effects of distractors on target recognition (Anderson, et al., 2011; Bergström, et al., 2016; Eriksen & Eriksen, 1974; Ste-Marie & Jacoby, 1993). The results suggest that intentional recognition judgements can be biased by unintentional recognition of distracting information in the same environment.

The ERP results replicated the previous finding (Bergström, et al., 2016) of a clear dissociation between two well-established ERP markers of recollection and familiarity (Rugg & Curran, 2007), consistent with dual process of recognition memory (Curran, DeBuse, & Leynes, 2007). Converging with behavioural results, the ERPs indicated that participants showed evidence of familiarity to both old targets and distractors. Although participants were instructed to focus only on the words in the Memory Stroop task, they still showed more positive FN400 to old than new distractors, suggesting that distractors were processed automatically. Furthermore, the parietal old/new effect indicated that further processing for recollection was present only for old targets but not for old distractors, indicating that intentional recognition was specific to old target items. Overall, the results replicated the neural evidence from an earlier study (Bergström, et al., 2016) that suggests unintentional recognition of distractors and its effects on target recognition is driven by familiarity rather than recollection.

Behavioural results were weak so it was expected not to see a WM influence on SR effect with ERPs. The only difference between WM load conditions was found on FN400 and it did not interact with target and/or distractor. The difference in FN400 seems like a component overlap in the frontal scalp and it could not suggest modulation of FN400. However, this finding might suggest that WM was activated in the early stage of recognition, around the same time with the FN400 familiarity ERP effect. Proactive control was be associated with sustained and/or anticipatory activation of lateral PFC, which indexes the active maintenance of task goals that requires high cognitive demand (Braver, 2012). Accordingly, this evidence supports the proactive control account which suggests an early mechanism that controls and orients attention toward goal-related tasks. Furthermore, the observed difference might support the proactive control account, since research suggests only proactive control employs WM resources (Braver, 2012; Burgess & Braver, 2010). Moreover, the hemispheric activity for high and low WM load conditions were differed; in high WM load condition both hemispheres elicited greater LPN for high WM in contrast, only left hemisphere was activated for low WM load condition. This finding may suggest that the recruitment of processes indexed by LPN was greater for high WM load condition as it was emerged in both hemispheres.

The ERP results demonstrated that to-be ignored distractors are still processed automatically, which may then presumably lead to a response conflict between targets and distractors if the correct responses for the two stimuli were different. Hence, reduced accuracy for incongruent trials (old target/new distractor and new target/old distractor) may be due to a conflict. Consistent with this view, new target old distractor pairings triggered a larger LPN than old target new distractor pairings, suggesting that response conflict caused by unintentional distractor recognition when the target required a "new" response created a more negative LPN. (Johansson & Mecklinger, 2003) reviewed the evidence that early frontal and later parietal old/new effects are sometimes followed by an LPN that is greater for old items compared to new items. They divided studies into two groups according to their separate contributions to the LPN: (a) memory tasks that required additional post-retrieval monitoring due to response conflict (b) memory tasks that require retrieval of source or contextual information. The results were consistent with the view that the LPN is related to post-retrieval monitoring in situations of high response conflict (Hu, Bergström, Bodenhausen, & Rosenfeld, 2015). That is, participants should have the highest need to monitor and evaluate familiarity signals from distractors when the target is new compared to when the target is old. Because new distractors did not elicit familiarity signals, they also did not recruit post-retrieval monitoring processes even when presented incongruently with old targets.

Considered together, ERPs and behavioural findings suggest that the effect of WM on SR was weak. Related to the failure to find behavioural and ERP evidence for interactions between distractor processing and WM load, there are also other studies that showed that high WM load does not always produce an increase in distractor processing. For instance, a recent fMRI study similarly found that, although there was an interaction between WM and distractor processing in brain activity in the inferior frontal gyrus, the interaction was not supported by the behavioural measurements (de Fockert & Theeuwes, 2012). Moreover, Carmel, Fairnie and Lavie (2012) suggested that WM might affect distractor processing only when distractor stimuli are sufficiently salient. As such, their results revealed that the distractor interference was greater for more salient faces compared to non-salient buildings. Similarly, in this experiment emotional pictures might have been attention grabbing that which might have stopped participants to process them (De Fockert, 2013). With really salient distractors, distractor bias is still there even with the WM load. Furthermore, few studies found that distraction was reduced under high working memory load (Berti & Schröger, 2003; SanMiguel, Corral, & Escera, 2008) however the WM task in those experiments (0-back and 1-back tasks which were considered too easy for young adults) may have insufficiently loaded WM.

Conclusion

I investigated the underlying neural processes of the biasing effect of distractors on target recognition and how this may be modulated by working memory load using EEG. The results replicated the previous findings on intentional (target) and unintentional (distractor) processing that the neural and memory processes are dissociable for unintentional and intentional recognition. ERP results also indicated, early processing in high WM load compared to low WM load conditions suggesting an activation of proactive control in the face of an interference. A novel finding of the research is that the retrieval monitoring was found to be greater when new targets presented with old distractors.

Chapter 4

Does confidence in intentional recognition decisions covary with distractor-induced recognition biases?

The main aim of this study was to explore the relationship between the SR effect (lower accuracy for incongruent than congruent memory Stroop trials) and confidence judgments associated with recognition decisions to target stimuli. As previous research demonstrated (Anderson, et al., 2011; Bergström, et al., 2016) the SR effect arises from unintentional recognition of distractors, which biases target recognition judgements.

According to the signal detection theory, confidence is directly related to the memory strength, as a result, accuracy and confidence tend to covary. High confidence decisions for targets found to be correlated with higher accuracy, and this relationship is linked with the contribution of recollection (Yonelinas, 2001). However, distraction also influences confidence decisions along with target accuracy. For instance, Beaman and Jones (1997) investigated the influence of auditory distraction by asking participants to ignore non-sense words during a two-alternative forced-choice recognition task. They found impaired recognition on distraction condition compared to non-distraction condition suggesting that auditory distraction impairs memory access directly. It is possible that participants could shift their criterion to compensate for distraction. In case of a distraction, participants may become less confident of their candidate responses, so that fewer of them passes the criterion. Alternatively, participants may have become more cautious and adopt a more stringent criterion. A study found that distraction did not reduce correct responses but increased the number of incorrect responses (Perfect, Andrade, &

Eagan, 2011). Researchers argued that participants reacted to the distraction by adopting a more liberal criterion, thus volunteering candidate responses held with lower confidence. Beaman, Hanczakowski and Jones (2014) investigated the influence of distraction on resolution, a metacognitive process that shows the ability to distinguish between their correct and incorrect responses indexed by confidence judgements. Their results showed that distraction impairs resolution that is lower metacognitive monitoring of retrieval under distraction. Also, they found that participants have not tried to strategically compensate for the loss in the quantity of output under distraction by lowering their report criterion. Instead, participants used the same report criterion in all conditions.

Unintentional distractor recognition is considered to be automatic and triggers early memory processes (Bergström, et al., 2016) which may suggest that it occurs outside of awareness (see e.g. Paller, et al., 2007). Alternatively, participants may consciously experience familiarity to the distractors, but may be unable to resist the biasing effects of distractor recognition because they misattribute the conscious experience to the incorrect stimulus, or because they fail to override the incorrect motor response that is elicited by distractor recognition. However, previous research has not investigated how consciously distractors were processed when participants showed a distractor-induced recognition bias.

One factor that may help us understand this issue, and also the mechanisms underlying the SR effect more generally, could be participants' confidence in their recognition judgements to target stimuli. Participants might experience lower confidence for some judgements because they unintentionally but consciously recognise the distractors and experience response conflict at a relatively late, conscious stage of decision making. That is, they may subjectively detect that recognition decisions are being biased on the incongruent trials. This account would predict larger SR effects and more neural evidence of distractor recognition for low compared to high confidence target recognition judgements. In contrast, if unintentional recognition of distractors elicits only implicit memory signals that participants are unaware of, then the SR effect may not show any relationship with participants' subjective experience of confidence for their target recognition judgements.

Alternatively, the SR effect could be stronger for target recognition judgements made with low compared to high confidence because memory of the target is weaker (e.g. due to less effective encoding), which may make participants more susceptible to bias arising from memory signals from the distractor. Relevant to this point, Ste Marie and Jacoby (1993) investigated the effect of increased familiarity to distractors and targets on the SR effect by manipulating the number of repetitions of the distractors and targets during study presentation. However, their results were complicated, in that there was no evidence that the number of distractor or target repetitions per se influenced the SR effect, but rather, the largest effect seemed to arise when the number of repetitions of targets and distractors were congruent (i.e. when a target had been repeated the same number of times as its paired distractor during the study phase). Based on these findings, the authors suggested that the absolute familiarity of targets and distractors might not be an important modulator of the SR effect. However, their study did not take into account the subjective experience of memory, which may be a more direct measure of memory strength.

Pilot Study for Experiment 4

The first experiment in this chapter investigated whether the behavioural SR effect would covary with intentional recognition confidence, partly to pilot the changes to the behavioural task before a subsequent EEG study (presented in Experiment 4). The design included a typical memory Stroop manipulation where targets and distractors were presented together and could both be either old or new, and also working memory load was manipulated using an n-back task similar to the previous studies. In addition, participants were asked to report their confidence on target recognition decisions during the memory Stroop test, using a continuous scale. Next for each participant, the trials were split into separate bins for high and low confidence responses (based on a median split) and were calculated recognition accuracy and reaction times separately for these bins.

I hypothesized that overall, recognition of old (studied) targets paired with old distractor items would be more accurate compared to old targets paired with new distractors. Similarly, recognition of new targets paired with old distractor items would create less correct rejections compared to new targets paired with new distractors. These effects would be important indicators of occurrence of SR. Moreover, as participants' confidence in their judgements is typically positively related to retrieval accuracy (Busey, et al., 2000), participants should be more correct for high than low confidence judgements. In line with my previous studies, I also predicted that, in the light of the findings from Experiment 1, the SR effect was expected to be observed with 2-back rather than with 1-back WM task. However, the changes in the methodology, that is requiring participants to indicate their subjective confidence levels, might undermine the influence of WM on SR. The relationship between confidence and working memory has never been directly investigated.

However, making confidence judgements requires several cognitive processes which are also needed for working memory. For example, to make a confidence judgement, one would compare the memory with a criterion which would require an online activation and manipulation of memory and the criterion. Furthermore, confidence judgements are usually followed by monitoring the decision before or after the response was given (Koriat & Goldsmith, 1996). Participants monitor the contents of their memory and assess the different strengths of the stored items. This assessment becomes the basis for their confidence judgment. A study found a greater activation in the right dorsolateral prefrontal cortex for correct low than correct high confidence judgements (Henson, et al., 2000). Therefore, asking participants to evaluate their confidence levels might also create an additional working memory load. This might reflect in the occurrence of the SR effect even in the situations with low WM load. Finally, and most importantly, I wanted to test whether the SR congruency effect covaried with target recognition confidence. If participants experienced conscious response conflict or were more susceptible to distractor-induced bias when their target memory was weaker, then the SR effect should be larger for low than high confidence responses. However, if participants were unaware of distractor recognition causing a bias or the bias is not modulated by target memory strength, then the SR effect should be found regardless of target recognition confidence.

Methods

Participants

The data were collected from 39 participants. Two participants were eliminated due to poor performance in the n-back task (below 50% accuracy). Thirty-seven healthy young adults (22 assigned to 1-back condition and 15 assigned to 2-back condition), undergraduate students from department of Psychology recruited from University of Kent made up the final sample. Participants were between 18-21 years old (6 males, M_{age}=19, SD_{age}=0.82; 31 females, M_{age}=18.7, SD_{age}=0.84). They received course credit or were given money for their participation.

Design

The design of the study was a 2 (target type: old, new) x 2 (distracter type: old, new) x 2 (working memory load: low; 1-back, high; 2-back) x 2 (confidence: high, low) mixed factorial design with target type, distractor type and confidence as within subjects factors, and working memory load as a between subjects factor. Figure 5.1 shows the schema of the design and representative stimuli.

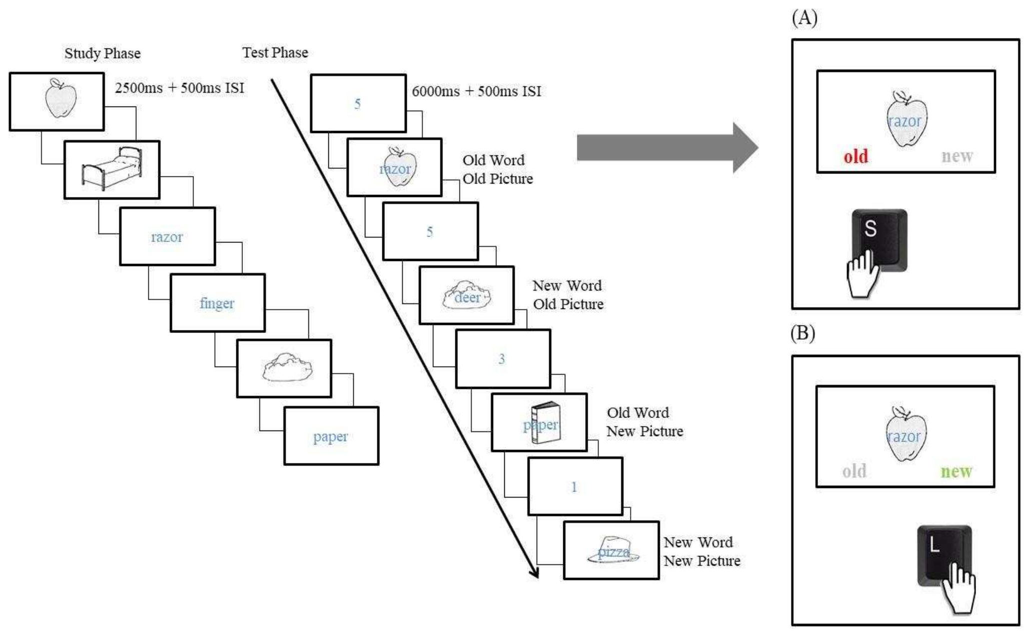


Figure 4. 1. Illustration of the experimental procedure: In the test phase, participants make confidence judgements on their target recognition, upper left panel (A) demonstrates a very high confident (indicated by colour red) old response (indicated by key ‘S’) whereas lower left panel (B) demonstrates a low confident (indicated by colour green) new response (indicated by key ‘L’).

Stimuli

132 words and 132 pictures were used for stimuli in the Memory Stroop task. Pictures were single line, simple drawings in black and white and they were taken from (Bonin, et al., 2003; Snodgrass & Vanderwart, 1980)(retrieved from: http://leadserv.u-bourgogne.fr/bases/pictures/) and words were selected from ELEXICON project database (http://elexicon.wustl.edu/). The words selected by length (3-6 letters), only nouns and concrete words were used. They were presented in blue 60-point Arial font. Pictures and words were randomly paired for the memory test with the restriction that the picture and word should not be semantically related.

Procedure

After giving information and having signed the informed consent from participants, they were taken to a quiet room with a computer set up. The experiment started with a practice round which followed by 10 rounds of study and test phases interleaved with the working memory task. In study phase, participants were shown 12 pictures and 12 words for 2500ms with an ISI of 500ms which were presented randomly intermixed for each participant. Participants were asked to memorize the words and pictures. They were asked to switch between two tasks during the test phase (see Figure 4.1). The first task was an n-back task which is widely used in the literature for the manipulation of working memory. In this task, participants were asked if the number on the current trial was the same with the number “n” trials before. Two different levels (1-back/2-back) of the n-back task was used. Participants were instructed to press the ‘S’ (for same) or ‘L’ (for different) keys. Behavioural outputs for the n-back task were reaction times and response accuracy (hits and correct rejections). The second task was the memory Stroop task (MST) task developed by Anderson, et al., (2011). In this task, participants were required to make recognition (old/new) judgements to the words when displayed simultaneously with the pictures. Each test phase included 24 words superimposed on 24 pictures. Pictures and words were randomly paired and pairings were different across all participants. There were four conditions: new words and new pictures (6 trials), new words and old pictures (6 trials), old words and new pictures (6 trials) and old words and old pictures (6 trials). Each test block included an equal number of the four item types. In the test phase, participants were instructed to ignore the pictures and make their recognition judgements only based on the oldness of the words (did you see the word before in the study phase or not). Participants were also asked to make a decision about how confident they were about their recognition judgement by pressing the ‘old’ or ‘new’ keys for longer or shorter. As they held in the keys, labels displayed on the screen that indicated the response options (old, new) would gradually change colour, specifically for their chosen option. That is, if participants pressed a key to indicate that the item was new, the “new” label would change its colour, and the amount of change would depend on the duration of the key release. Participants were informed that they should show their confidence on a colour continuum (from green to red). Pressing the keys briefly resulted in a green colour that indicated low confidence, whereas holding the keys for longer (max 2500ms) would change the colour more towards red, which indicated high confidence. The inter stimulus interval (ISI) between a memory Stroop trial and an n-back trial was 500ms and the duration of each Memory Stroop stimulus was 2500ms. The screen showing the test items was presented until participants’ response or terminated at the end of 6000ms. Stimulus presentation and response collection was conducted with an open source computer programme developed by Jonathan Pierce (PsychoPy 2.0).

Results

Analysis of N-back task

Accuracy in high WM load condition varied from 96% to 50% whereas it ranged from 98% to 51% in low WM load condition. The n-back performance accuracy and reaction times were compared between 1-back and 2 back with independent samples t-test. For accuracy, there was a significant difference between 2-back and 1-back, t (35) = 2.96, p=0.006. Participants were more accurate in the 1-back task compared to 2-back task (2-back, M = 0.77, SD = 0.13, 1-back, M = 0.89, SD = 0.10). These differences between low and high WM load conditions thus confirmed that the manipulation of WM load had been successfully implemented and ruled out a speed-accuracy trade-off (see Figure 4.2).

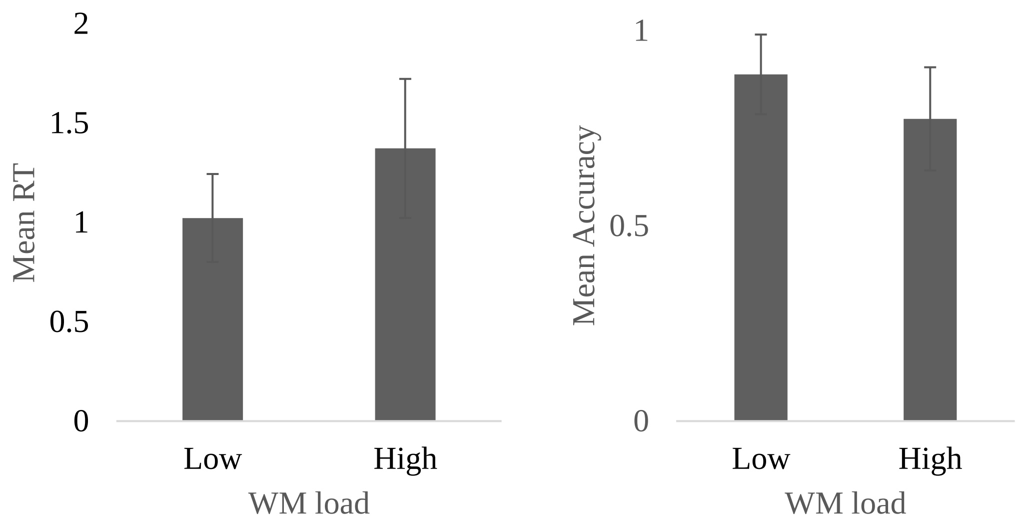


Figure 4. 2. Means and standard deviations of accuracy (right graph) and RT (left graph) for High and Low WM Conditions

For reaction times, there was a significant difference between 2-back and 1-back, t (35) = 3.73, p=0.001, Participants were significantly slower in the 2-back task compared to 1-back (2-back, M = 1373ms, SD= 350ms, 1-back, M = 1022ms, SD =

221ms). These results indicate that the manipulation of WM load was successfully implemented.

Analysis of Memory Stroop

Confidence judgments were collected as continuous data (the latency of key press), therefore it was necessary to process the data to transform them from a continuous to categorical variable. First, the median confidence level per participant, per condition was calculated. Then, each trial was categorised as high confidence if the confidence was higher than the median score for the specific participant and condition and categorised as low confidence if the confidence was lower than the median score for the specific participant and condition. This was done to take into account possible differences in the confidence criterion across participants and resulted in equal number of trials contributing to high versus low confidence conditions. Next, mean accuracy was calculated separately for each target (old/new) and distractor (old/new) condition according to confidence levels (high and low) for each participant in order to analyse the data in a mixed measures ANOVA design, with the added between-subjects factor of n-back group (1 and 2). Mean scores and standard deviations of accuracy are displayed in Table 4.1.

Table 4. 1. Mean accuracy (hit and correct rejection rates) and their standard deviations for target type, distractor type and confidence levels for high and low WM load conditions.

		Old Target		New Target	
		Old Distractor	New Distractor	Old Distractor	New Distractor
Low Confidence	1- back	0.73(0.19)	0.73 (0.21)	0.77 (0.21)	0.86 (0.11)
	2 - back	0.71 (0.13)	0.64 (0.22)	0.84 (0.18)	0.87 (0.15)
High Confidence	1- back	0.92 (0.14)	0.91 (0.14)	0.84 (0.27)	0.93 (0.13)
	2 - back	0.93 (0.09)	0.86 (0.15)	0.92 (0.13)	0.91 (0.17)

Note: Old target scores show hits, new target scores show correct rejections.

Firstly, a 2 (target type: old, new) x 2 (distracter type: old, new) x 2 (working memory load: low; 1-back, high; 2-back) x 2 (confidence: high, low) mixed ANOVA was conducted. The analysis revealed a significant interaction between target and distractor. A paired samples t-test used to compare the accuracy of old distractors and new distractors separately for old and new target decisions. Analysis revealed that participants were more accurate to old targets when they were paired with old than new distractors ($t\ (32) = 2.27$, $p=0.03$), similarly participants were more accurate to new targets paired with new than old distractors ($t\ (32) = 2.07$, $p=0.05$). The main effect of WM load was non-significant.

There was a significant interaction of distractor and WM. Paired samples t-test on collapsed means for target and confidence revealed that participants were more accurate to targets paired with new compared to old distractors on 1-back (t (21) = 1.96, p=0.06), but there was an opposite pattern in 2-back, participants were more accurate to targets paired with old compared to new distractors, (t (14) = 1.82, p=0.09). However, it should be noted that results from paired samples t-test were only marginally significant. Target, distractor and WM load was non-significant.

Finally, interaction of target and confidence was significant. Paired samples t-test on collapsed means for distractor type and working memory load condition revealed that the difference between old target (M=0.71, SD=0.17) and new target (M=0.83, SD=0.14) was significant for low confidence judgements (t (36) = 3.23, p=0.003), but not for high confidence judgements (t (36) = 0.43, p=0.67; see Figure 4.3).

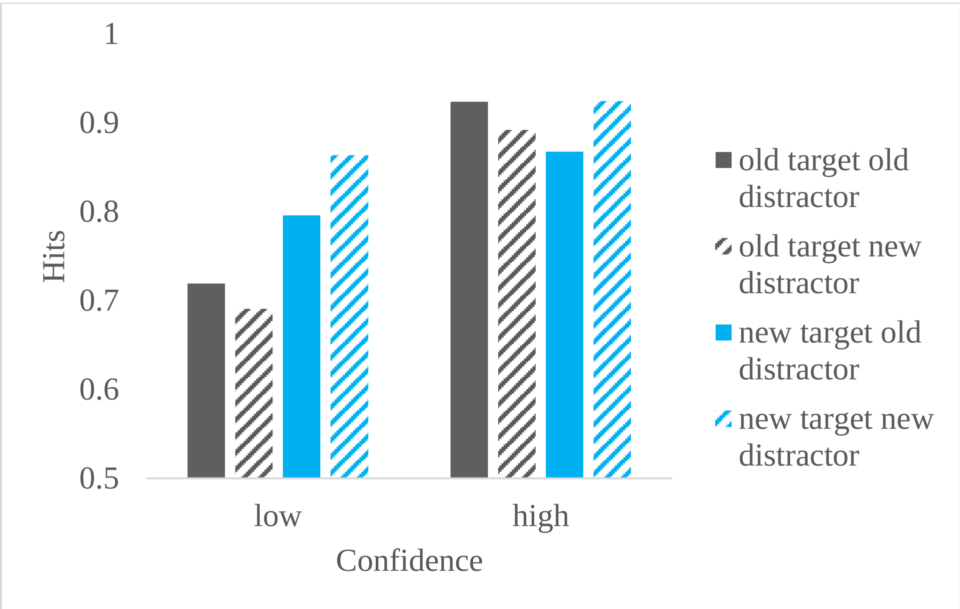


Figure 4. 3. Mean correct recognition responses separate for low (left) and high (right) confidence levels.

Table 4. 2. ANOVA results for Memory Stroop recognition accuracy

Source	
T	**F (1, 35) = 4.45, p = 0.042, ηp^2 = 0.11***
T X WM	F (1, 35) = 1.53, p = 0.23, ηp^2 = 0.42
D	F (1, 35) = 0.37, p = 0.55, ηp^2 = 0.01
D X WM	**F (1, 35) = 5.54, p = 0.02, ηp^2 = 0.14***
C	**F (1, 35) = 46.97, p < 0.001, ηp^2 = 0.57****
C X WM	F (1, 35) = 0.05, p = 0.83, ηp^2 = 0.001
T X D	**F (1, 35) = 5.55, p = 0.02, ηp^2 = 0.14***
T X D X WM	F (1, 35) =0.005, p = 0.82, ηp^2 = 0.001
T X C	**F (1, 35) = 18.41, p < 0.001, ηp^2 = 0.35****
T X C X WM	F (1, 35) = 0.57, p = 0.46, ηp^2 = 0.02
D X C	F (1, 35) = 0.12, p = 0.73, ηp^2 = 0.004
D X C X WM	F (1, 35) = 0.13, p = 0.72, ηp^2 = 0.004
T X D X C	F (1, 35) = 0.08, p = 0.79, ηp^2 = 0.002
T X D X C X WM	F (1, 35) = 0.35, p = 0.59, ηp^2 = 0.01

T= Target, D=Distractor, C=Confidence, *p<0.05, **p<0.001

Discussion

The first aim of this study was to replicate the previous findings of the SR effect, and to make sure the SR effect could be observed even with the additional task requirements for participants to make confidence judgements (for the purpose of piloting the task for an EEG study). It was also important to determine whether the SR effect would be modulated by working memory load, more specifically, whether high WM load would create more SR, and also whether WM would influence confidence judgements.

Previous findings on SR were replicated with this study (Anderson, et al., 2011; Bergström, et al., 2016). Firstly, there was a clear congruency effect; participants were more accurate to old targets when they were paired with old than new distractors and were more accurate to new targets when they were paired with new than old distractors. This finding indicates that the to-be ignored old distractors were unintentionally processed and biased target recognition decisions. The unintentional recognition signal coming from distractors combined with the recognition of targets and resulted in more accurate recognition when both targets and distractors were congruent (old-old; new-new) compared to incongruent (old-new; new-old). Moreover, the results suggested that this SR effect was present regardless of participants' confidence levels; the same pattern was observed for both high and low confidence judgements. Instead, confidence did significantly covary with recognition accuracy for old targets (i.e. hit rate), which was significantly lower for low compared to high confidence responses. These findings indicate that participants may not be consciously experiencing response conflict when biased by distractor recognition, but rather, their target responses appear to be biased outside of awareness, and regardless of target memory strength.

In this experiment, the influence of WM load on the SR effect was not replicated, however it is important to note that the power of the study was very low and may have been insufficient to determine such differences due to relatively smaller sample size. Furthermore, our results showed that WM load did not influence confidence judgements. However, we found that the WM load manipulation did have some influence on distractor processing. Distractors did not affect participants' accuracy in the low WM load condition, whereas dividing attention with a high WM load task made the distractors influence recognition judgements; as reflected in more accurate answers to targets when they were paired with old compare to new distractors. This pattern is in line with (Lavie & De Fockert, 2005), who showed that the processing of distractor is greater under dual-task compared to single-task conditions and in high WM load compared to low WM load conditions. Hence in the next EEG study, WM load was not manipulated but we used the more powerful high load (2-back task) in order to ensure that the basic SR effect would be detected.

Experiment 4

In Experiment 4, I used a similar design to the pilot study with the exception that all participants conducted the high WM load 2-back task as a secondary task, and the addition of EEG recordings during the Memory Stroop task to investigate further the neural mechanisms underlying the SR effect. The benefits of using EEG with this task is that it allowed me to separate the memory processes that occurred for distractors and targets, and also separate different stages of retrieval processing, such as initial memory activation from post-retrieval monitoring processes that participants engage to evaluate whether retrieved information is likely to be accurate (Higham, Luna, & Bloomfield, 2011). The latter may in fact be a particularly relevant process to investigate in relation to recognition confidence in the current paradigm, as outlined below.

There are several studies that attempted to provide a link between retrieval monitoring and confidence. For example, research showed that retrieval, monitoring, and setting a report threshold is affected by distraction, and both the response and monitoring processes affect confidence levels (Goldsmith, Pansky, & Koriat, 2014). In one attempt to disentangle the neural correlates of retrieval success from retrieval monitoring, participants were asked to indicate the confidence of each of their old-new decisions during a word recognition task (Henson, et al., 2000). Researchers found that the right DLPFC (a region that was hypothesised to mediate retrieval monitoring) showed a greater response for low than high confidence judgements.

Moreover, an LPN-like negativity, which is an ERP marker of retrieval monitoring (Johansson & Mecklinger, 2003), has been found for correct recognition judgements made with low confidence with widespread topography (Addante, Ranganath, & Yonelinas, 2012). These findings thus suggest that participants engage more retrieval monitoring when they make low confidence judgements compared to high confidence judgements.

In addition to retrieval monitoring, confidence is also related to the accuracy of recognition memory decisions (Brewer & Sampaio, 2006; Busey, et al., 2000) and for recognition of old items, confidence seems to be related to the strength of memory and/or amount of information retrieved. Previous studies have found that for intentional recognition, high confidence is associated with enhanced positive ERPs for recognised old items for both FN400 and left-parietal ERP old/new effects (e.g. Curran, 2004). That is, the typical old>new ERP effects that have been related to familiarity and recollection respectively are enhanced for high compared to low confidence responses. This finding suggests that old items that are intentionally recognised with high confidence may do so because they elicit stronger familiarity signals and recollection of more contextual information than old items that are recognised with low confidence. However, no previous studies have investigated how unintentional recognition of distractors covaries with confidence on an intentional recognition task.

Therefore, the main research question of this study was to investigate the neural correlates of the SR effect and how it would relate to confidence in recognition decisions. The pilot study revealed no difference in the SR effect for recognition judgements made with high and low confidence. However, the accuracy of target recognition covaried with the level of confidence; old targets were identified less accurately when the recognition judgement made with low confidence, whereas recognition of new and old targets were similar when the recognition judgement made with high confidence. This behavioural pattern suggests that confidence judgements are more related to intentional target recognition than unintentional distractor recognition, hence that ERP markers of unintentional distractor recognition (as evident in the FN400 effect for distractors) might be relatively similar across high and low confidence responses, but that the ERP markers of target recognition (FN400 and left parietal old/new effects for targets) might be reduced for low compared to high confidence responses (in line with previous findings, e.g. Curran, 2004). Additionally, our previous study presented in Chapter 3 demonstrated that participants engage retrieval monitoring processes whilst they make recognition judgements, as indexed by the LPN effect. Thus, we hypothesized that similar retrieval monitoring processes would be observed in this experiment and they would be more prominent for low confidence judgements compared to high confidence judgements.

Methods

Participants

Thirty-one right-handed, native English speakers participated (M_{age} =20.08 years, SD=0.89, range 18- 40= years, 24 female and M_{age} =18.78 years, SD=0.67 range 18- 20= years, 9 male). Participants received course credit or were given money for their participation. All participants gave written informed consent, and the experiment was approved by the University of Kent Psychology Research Ethics Committee.

Design

The materials and design were similar to the pilot study with several changes to make the design compatible for EEG recording. (a) A fixation cross was presented for 500ms before each trial in both study and test phases. (b) In the test phase, stimuli were presented for 2000ms before requiring a response, and only after the end of 2000ms would a response selection become available. Participants are asked to delay their responses until the response selection options appeared on the screen in order to avoid visual and motor confounds in the EEG time-window of interest. After the response options appeared, a time window of 2500ms was given to make recognition/confidence judgements. It should be noted that such delayed responses were implemented only for the memory Stroop task. (c) In the previous experiment, the slowest responses for the n-back task never exceeded 2500ms, therefore to make the experiment shorter we reduced the trial duration in the n-back task from 6000ms to 2500ms. (d) This experiment was conducted only using the 2-back task as the aims of the study focused on the role of confidence rather than WM load in the SR effect.

EEG Recording and Analysis

EEG was recorded at 500 Hz with a 0.05- to 70-Hz bandwidth. The reference electrode was set to FCz and 64 scalp electrodes placed in an actiCAP according to the extended 10–20 system (Brain Products GmbH, München, Germany). Eye movements were measured and recorded from below the left eye (vertical EOG) and from the right outer canthi (horizontal EOG). Continuous EEG data from all channels were imported into EEGLAB and were analysed using EEGLAB (UC San Diego; Delorme & Makeig, 2004). The EEG was re-referenced to the average of the mastoids and epoched using a 200ms pre-stimulus baseline period and a 1500ms post-stimulus that was time-locked to the onset of the word–picture pair in the test phase. After concatenating epochs, large artefacts due to subject's motion, facial movements, or other sources of noise were manually deleted. Epochs were submitted to independent component analysis using Runica from the EEGLAB toolbox, with default extended-mode training parameters (Delorme & Makeig, 2004). Independent components reflecting eye movements and other sources of noise were identified by visual inspection of component scalp topographies, time courses, and activation spectra and were discarded from the data. Corrected data were high-pass filtered digitally at 30 Hz. Finally, any trials that still contained artefacts after filtering visually inspected and were removed. Only a small percentage of trials (11%) were deleted in total. Final ERPs were formed for the eight conditions: old word old picture low confidence (mean trial numbers =28.48), old word old picture high confidence (mean trial numbers =28.70) old word new picture low confidence (mean trial numbers =28.58), old word new picture high confidence (mean trial numbers =28.47), new word old picture low confidence (mean trial numbers = 28.67), new word old picture high confidence (mean trial numbers = 27.85) and new word new picture low confidence (mean trial numbers =29.21), and new word new picture low confidence (mean trial numbers =28).

For statistical analysis, time-windows were chosen to measure average amplitudes for the early and late old/new effects corresponding to familiarity and recollection-based processing, respectively, plus later time windows for measuring the LPN effect associated with retrieval monitoring. Average amplitudes were extracted from 300 to 500ms for the mid-frontal electrode (Fz) for the early old/new effect, and from 500 to 800ms for the left parietal electrode (P3) for the late old/new effect, in line with Bergström et al. (2016). The LPN was measured between 500 to

1500ms from left parieto-occipital (PO7) and right parieto-occipital (PO8) electrode sites using two separate time windows; 500 to 1000ms and 1000 to 1500ms. We included a late time window (1000 to 1500ms) different from previous research on the SR effect (Chapter 3 and Bergström, et al., 2016) because of two reasons. First, Bergström, et al. (2016) conducted a PLS analysis for 0 to 1000ms and they observed a sustained negativity from 500 to 1000. However, they did not test or specify whether the effect was prolonged. Furthermore, Herron (2007) defined two LPN subcomponents and they argued the 600-1900ms time window reflect mnemonic aspects of the task, such as search for episodic features and maintenance of the retrieved information. Secondly, participants were asked to withhold their answers until the response labels displayed (for 2000ms) therefore, this enabled us to investigate a longer time-window without motor response artefacts. The mean amplitudes for time windows were extracted and statistically analysed in IBM SPSS Statistics for Windows (Version 22.0, IBM Corp., Armonk, NY, USA).

Results

Behaviour

Analysis of Memory Stroop task

For the Memory Stroop task, we analysed accuracy (hit rates and correct rejection rates), as presented in Table 4.3.

Table 4. 3. Means and Standard Deviations (SD) of Accuracy for Target Recognition Decisions

	Old Target		New Target	
	Old Distractor	New Distractor	Old Distractor	New Distractor
Confidence	M (SD)	M (SD)	M (SD)	M (SD)
Low	0.63 (0.15)	0.59 (0.16)	0.71 (0.16)	0.73 (0.17)
High	0.90 (0.11)	0.87 (0.13)	0.79 (17)	0.82 (0.16)

Statistical analysis of accuracy data (proportions hits and correct rejections) was conducted with a 2 (target type: old, new) x 2 (distracter type: old, new) x 2 (confidence: high, low) within subjects ANOVA. Analysis revealed non-significant main effects of target and distractor types (F (1, 32) = 0.28, p=0.60; $F<0.001$, p=0.99, respectively). However, we found a significant interaction effect of target and distractor, (F (1, 32) = 6.69, p=0.01, $\eta p^2=0.17$). Paired samples t-tests conducted on collapsed means for high and low confidence measurements. Analysis revealed that accuracy was higher for old target and old distractor pairings compared to old target and new distractor pairings, (t (32) = 2.27, p=0.03), and new target and new distractor pairings compared to new target and old distractor pairings ($t(32) = 2.07$, p=0.05), (see Table 4.4). In addition, a significant difference was found between the high and low confidence judgements, (F (1, 32) = 128.64, $p<0.001$, $\eta p^2=0.80$). Participants were more accurate in their high confidence judgements compared to low. The interaction of confidence and target type was found significant ($F(1, 32) = 23.33$, $p<0.001$, $\eta p^2=0.42$; see Figure 4.3). Paired samples t-tests were conducted to identify the nature of the interaction. Results indicated that participants were more accurate to old targets compared to new targets in their high confidence judgements ($t(32) = 2.95$, $p=0.006$), whereas, they were less accurate to old targets compared to new targets in their low confidence judgements ($t(32) = -2.55$, $p=0.02$).

Table 4. 4. ANOVA results for Memory Stroop recognition accuracy

Source	
T	$F(1, 32) = 0.28$, $p=0.60$, $\eta p^2 = 0.01$
D	$F <0.001$, $p=0.99$, $\eta p^2<0.001$
C	$F(1, 32) = 128.64$, $p<0.001$, $\eta p^2 = 0.80$
T x D	**$F(1, 32) = 6.69$, $p=0.01$, $\eta p^2 = 0.17$***
T x C	**$F(1, 32) = 23.33$, $p<0.001$, $\eta p^2 = 0.42$****
D x C	$F(1, 32) =0.43$, $p=0.52$, $\eta p^2 = 0.01$
T x D x C	$F(1, 32) =0.29$, $p=0.60$, $\eta p^2 = 0.01$

T= Target, D=Distractor, C=Confidence, *p<0.05, **p<0.001

ERPs

Grand-averaged ERPs from the mid-frontal (Fz) and left parietal (P3) electrode sites for high and low confidence levels are displayed separately in Figure 4.4.

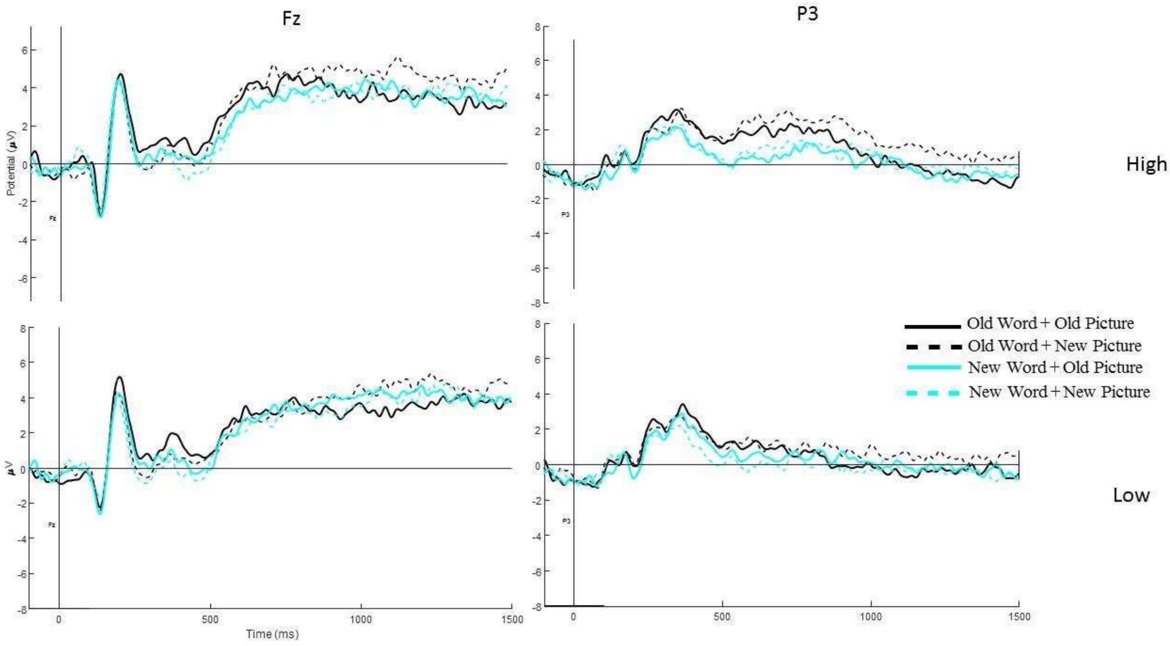


Figure 4. 4. Grand-average ERPs of old/new effects for targets and distractors. ERPs from mid-frontal (Fz, left column) and left parietal (P3, right column) sites for high (upper panel) and low (lower panel) confidence decisions.

FN400- Old/New Effects

The first analysis investigated mean amplitudes at 300-500ms at the mid-frontal site (Fz) that is thought to index familiarity, with a 2 (target type: old, new) x2 (distractor type: old, new) x2 (confidence: high, low) within subjects of ANOVA. Both old targets ($F(1, 32) = 4.74$, $p = 0.04$) and old distractors, ($F(1, 32) = 4.95$, $p = 0.03$) elicited significantly more positive FN400 amplitudes than new targets and new distractors, respectively (see Figure 4.5), replicating previous findings (Chapter 3, and Bergstrom et al., 2016).

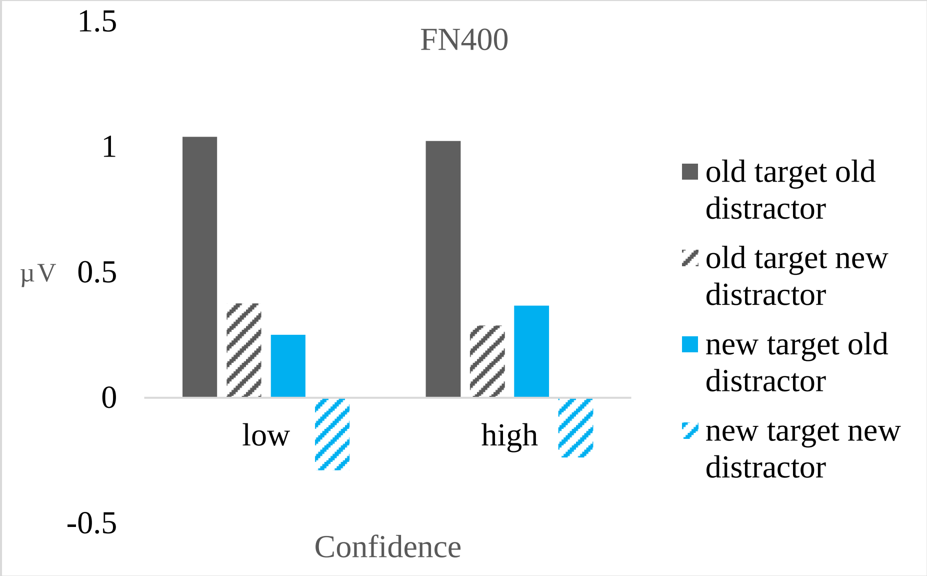


Figure 4. 5. Mean Fz amplitudes between 300-500ms for the different target and distractor types separate for low (left) and high (right) confidence levels.

Table 4. 5. Tests of Within-Subjects Effects on ERPs of FN400

Source	F (1, 32)	p	ηp^2
T	**4.74**	**0.04***	**0.13**
D	**4.95**	**0.03***	**0.13**
C	0.003	0.96	<0.001
T * D	0.05	0.83	0.001
T * C	0.07	0.79	0.002
D * C	0.02	0.89	0.001
T * D * C	<0.001	0.99	<0.001

T=Target, D= Distractor, C=Confidence, *p<0.05, **p<0.001.

Parietal old/ New Effects- Late Positive Component (LPC)

Next, I investigated mean amplitudes at 500-800ms at the left-parietal site (P3) that is thought to index recollection, with a 2 (target type: old, new) x2 (distractor type: old, new) x2 (confidence: high, low) within subjects of ANOVA. In contrast to the FN400, a typical increased parietal positivity for old compared with new items was only found for word targets, $F(1, 32) = 11.18$, $p = 0.002$, $\eta p^2 = 0.26$, also replicating previous findings (Chapter 3, and Bergström, et al., 2016). In addition, we found a significant main effect of confidence, $F (1, 32) = 7.93$, $p=0.008$, $\eta p^2=0.20$, whereby parietal ERPs in this time-window were more positive for high compared to low confidence responses (see Figure 4.6.). Both the single-process and dual-process recognition memory models predict that the parietal old/new effect should be affected by confidence in recognizing old items, but they differ with respect to predicted effects of confidence on new items. Previous research and behavioural findings indicate that the recognition of old targets compared to new targets will be larger for high confidence than low confidence responses (Curran, 2004). Therefore, the target and confidence interaction had a directional hypothesis ($F (1, 32) =2.59$, $p= 0.06$, $\eta p^2=0.08$, one-tailed). Indeed, paired samples t-tests indicated that there was a significant difference between old and new targets when recognition decisions were made with high confidence ($t (32) = 3.73$, $p= 0.001$) but not with low confidence ($t (32) = 1.79$, $p= 0.08$). Further, analyses revealed a significant difference between low and high confidence judgements for old target, but not for new targets. LPC was more positive for high ($M_{high}=2.14$, $SD_{high}= 2.68$) than low confidence ($M_{low}=1.01$, $SD_{low}= 2.30$) judgements for old targets, but they were similar for new target ($M_{high}=0.61$, $SD_{high}= 2.74$; $M_{low}=0.25$, $SD_{low}= 2.56$). Main effect of distractor $F (1, 32) =0.45$, $p= 0.51$, $\eta p^2=0.01$, the target and distractor interaction, $F (1, 32) =0.44$, $p= 0.51$, $\eta p^2=0.01$; and the distractor and confidence interaction $F (1, 32) =1.88$, $p= 0.18$, $\eta p^2=0.004$ were not significant.

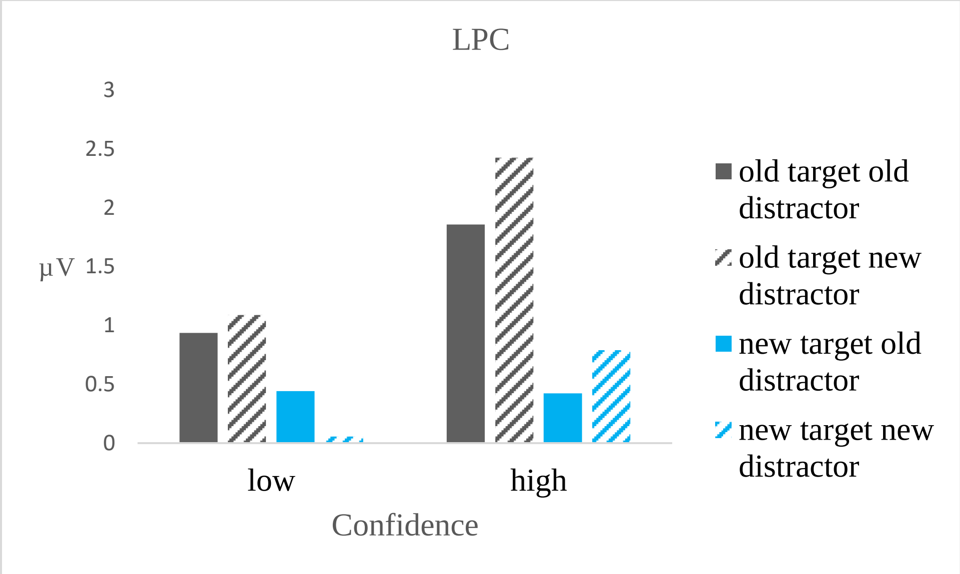


Figure 4. 6. Mean P3 amplitudes between 500-800ms for the different target and distractor types separate for low (left) and high (right) confidence levels.

Table 4. 6. Tests of Within-Subjects Effects on ERPs of LPC

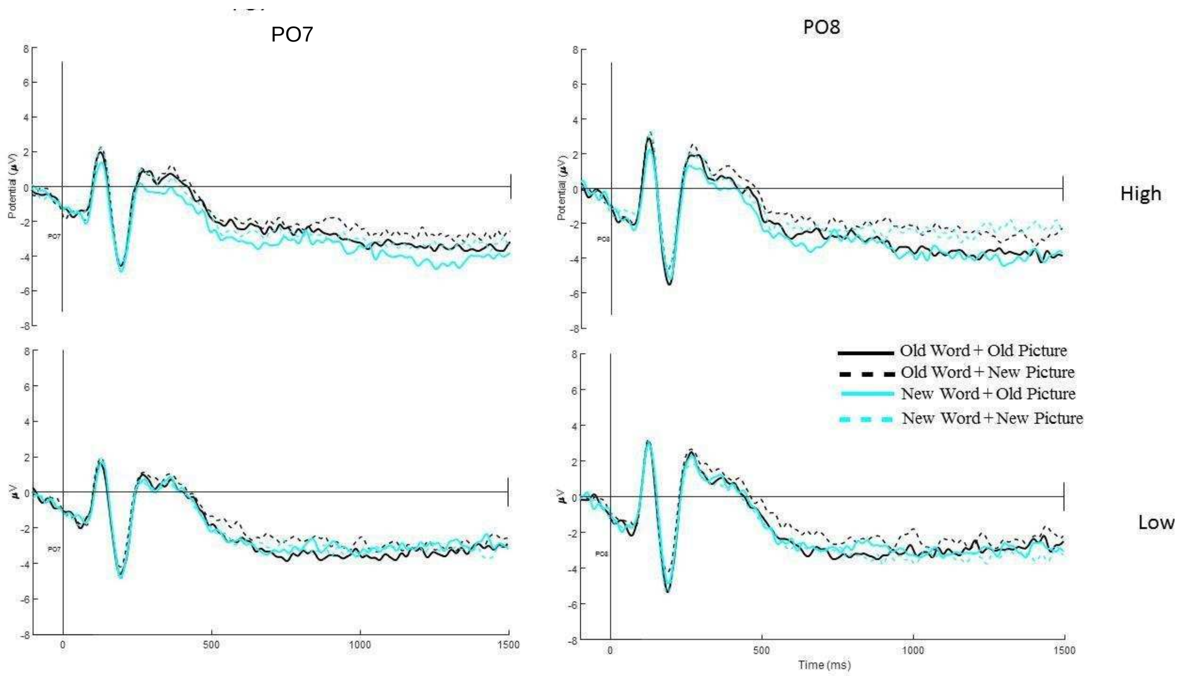
Source	F (1, 32)	p	ηp^2
T	**11.18**	**0.002***	**0.26**
D	0.45	0.51	0.01
C	**7.93**	**0.008***	**0.20**
T * D	0.44	0.51	0.01
T * C	2.59	0.12	0.08
D * C	1.88	0.18	0.06
T * D * C	0.13	0.72	0.004

T=Target, D= Distractor, C=Confidence, *p<0.05, **p<0.001.

Late Parietal Negativity (PO7 and PO8)

Grand-averaged ERPs from the left parietal (PO7) and right parietal (PO8) electrode sites for high and low confidence levels are displayed separately in Figure 4.7.

(A)



(B)

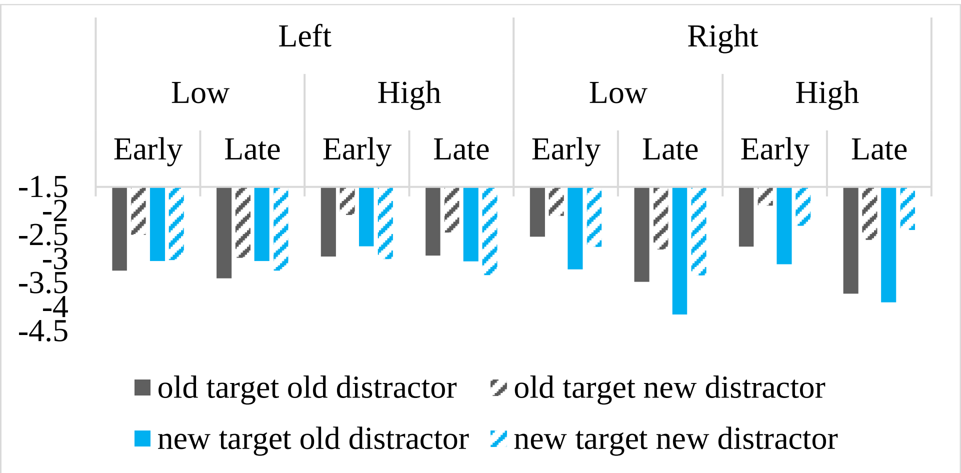


Figure 4. 7. (A) Grand-average ERPs of old/new effects for targets and distractors. ERPs from left parieto-occipital (PO7, left column) and right parieto-occipital (PO8, right column) sites for high (upper panel) and low (lower panel) confidence decisions. (B) Mean P07 (left) and PO8 (right) amplitudes between 500-1000ms (early) and 1000-1500ms (late) for the different target and distractor types separate for low and high confidence levels.

For statistical analysis of the LPN, a 2 (hemisphere: left, right) x 2 (time window: 500-1000ms, 1000ms- 1500ms) x 2 (target type: old, new) x 2 (distracter type: old, new) x 2 (confidence level: high, low) within subjects ANOVA (see Table 4.5. for details) was conducted.

There was a significant hemisphere x target x confidence interaction $F(1, 32) = 5.43$, $p = 0.03$ and a time x hemisphere x target x confidence interaction $F(1, 32) = 4.33$, $p = 0.05$. Therefore, separate 2 (hemisphere: left, right) x 2 (confidence: low, high) x 2 (time: early, late) ANOVAs for old and new targets were conducted. A significant interaction of hemisphere, time and confidence was found for new targets ($F(1, 32) = 8.04$, $p=0.008$), but not for old targets ($F(1, 32) = 0.52$, $p=0.48$). Then, separate analyses were conducted for left and right hemisphere which revealed a significant interaction of time x confidence, $F(1, 32) = 7.06$ $p=0.01$ in left hemisphere, whereas the same interaction was not significant in the right hemisphere, $F(1, 32) = 0.28$, $p=0.60$). Finally, separate paired samples t-tests for high and low confidence decisions (on new targets and left hemisphere) revealed a significant difference between early and late time windows in high confidence ($t(32)= 2.18$, $p=0.04$) but not for low confidence ($t(32)= 0.36$, $p=0.72$). LPN was more negative in late time window compared to early time window for decisions made with high confidence for new targets in left hemisphere.

In addition, distractor type interacted with confidence and time window $F(1, 32) = 4.96$, $p=0.03$ in the omnibus ANOVA. I conducted 2 (time windows: 500-1000ms, 1000ms- 1500ms) x 2 (confidence; high and low) repeated measures ANOVAs separately for old and new distractors (see Figure 4.7B). The interaction of time window and confidence was significant for old distractors ($F(1, 32) = 14.33$, $p=0.001$, $\eta p^2 =0.31$), but not for new distractors ($F(1, 32) = 1.10$, $p=0.30$, ηp^2

=0.03). Further, separate paired samples t-tests were for late and early time windows revealed a significant difference between early and late time windows for high confidence judgements ($t(32) = 2.95$, $p=0.006$), but not for low confidence judgements ($t(32) = 0.42$, $p=0.68$). LPN was more negative in late time window compared to early time window for decisions made with high confidence when the targets were paired with old distractors.

Table 4. 7. Tests of Within-Subjects Effects on ERPs of LPN

Source	F (1, 32)	p	ηp^2
H	0.32	0.58	0.01
TIME	3.31	0.08	0.09
T	1.35	0.25	0.04
D	3.68	0.06	0.10
C	<0.001	0.99	<0.001
H * TIME	0.08	0.78	0.003
H * T	0.04	0.85	0.001
TIME * T	0.43	0.52	0.01
H * TIME * T	0.001	0.98	. <0.001
H * D	1.03	0.32	0.03
TIME * D	0.15	0.70	0.005
H * TIME * D	0.88	0.36	0.03
T * D	0.59	0.45	0.02
H * T * D	0.05	0.83	0.001
TIME * T * D	0.68	0.42	0.02
H * TIME * T * D	1.23	0.28	0.04
H * C	0.02	0.89	0.001
TIME * C	**14.79**	**0.001**	**0.32**
H * TIME * C	2.13	0.15	0.06
T * C	0.12	0.73	0.004
H * T * C	**5.43**	**0.03**	**0.15**
TIME * T * C	0.32	0.57	0.01
H * TIME * T * C	**4.33**	**0.05**	**0.12**
D * C	1.36	0.25	0.04
H * D * C	1.46	0.24	0.04
TIME * D * C	**4.96**	**0.03**	**0.13**
H * TIME * D * C	0.26	0.61	0.008
T * D * C	1.51	0.23	0.05
H * T * D * C	0.10	0.76	0.003
TIME * T * D * C	0.006	0.94	<0.001
H * TIME * T * D * C	0.01	0.91	<0.001

T=Target, D= Distractor, C=Confidence, Hem= Hemisphere, Time= Time Windows, *p<0.05, **p<0.001

Discussion

Behavioural Results

As we conducted a pilot study, we expected to find the same results for the behavioural measurements. Initially, we expected to replicate the results on the SR effect and confidence, which we did. Firstly, target and distractor interaction revealed that participants were more accurate when they were responding to old targets paired with old distractors compared to old targets paired with new distractors, and new targets paired with new distractors compared to new targets paired with old distractors. This finding is in line with previous experiments in this thesis and previous research on the SR effect (Anderson, et al., 2011; Bergström, et al., 2016).

Secondly, high confidence judgements were more accurate than low confidence judgements. This finding fits well with the single process models especially with the global matching model which argues that the confidence in an old/new memory decision is related directly from the perceived familiarity of the test item, and confidence is used as an index of memory strength (see Van Zandt, 2000 for a review). Accordingly, participants' confidence ratings relate to the distance between the item's perceived memory strength and the decision threshold for responding "old" versus "new". Therefore, items that are recognised as old with high confidence have very high memory strength, and are therefore very likely to be truly "old" (Stretch & Wixted, 1998). In line with this account, research generally finds a positive correlation between memory accuracy and confidence (with some exceptions), suggesting that correct recognition judgements are related to higher confidence judgements (DeSoto & Roediger III, 2014; Nelson & Dunlosky, 1991).

Moreover, the main effect of confidence was qualified by a target and confidence interaction, since recognition decisions made with high confidence were more accurate for old compared to new targets, whereas decisions made with low confidence were similar for new compared to old targets. These results are similar to previous findings by Henson, et al. (2000), who also showed that the proportion of correct new judgements were similar for high and low confidence judgements, whereas a greater proportion of correct old judgements were made with high confidence than low confidence. This pattern suggests that recognition confidence is particularly related to memory strength for old items, consistent with ERP findings that old items that are recognised with high confidence elicit more positive ERPs (indicative of memory retrieval) than old items that are recognised with low confidence, whereas ERPs for new items are more similar regardless of confidence (Curran, 2004).

Interestingly, in this experiment we also replicated the finding that the behavioural SR effect was not modulated by target recognition confidence, as it was equally present for both high and low confidence responses. Thus, consistent with the pilot study, behavioural findings indicate that participants may not be consciously experiencing response conflict when biased by distractor recognition, but rather, their target responses appear to be biased outside of awareness, and regardless of target memory strength.

EEG Results

First, we expected to replicate the dissociation between unintentional recognition of distractors and intentional recognition of targets by comparing ERP markers of recollection and familiarity (Bergström et al., 2016). Indeed, the ERP marker of familiarity was present for both targets and distractors, as the FN400 was more positive for old than new targets and for old than new distractors. However, the parietal positivity which indexes recollection was only present for targets, since old targets elicited more positive ERPs across the parietal area than new targets. These results are in line with prior research showing a dissociation between these two ERP markers of recognition processes (Rugg & Curran, 2007; Wilding & Ranganath, 2011) and supports dual process models that consider familiarity and recollection as functionally independent processes (see Yonelinas, 2002, for a review). More specifically, the results replicated previous findings on the dissociable ERP correlates of unintentional recognition of distractors versus intentional recognition of targets (Bergström, et al., 2016).

There was also no evidence from ERPs that recognition of distractors was related to participants' confidence in their target recognition judgements, as the FN400 was not different for high and low confidence judgements. In contrast, later left parietal ERPs were more positive for high confidence judgements compared to low confidence judgements, converging with the behavioural results to suggest that confidence is more related to recognition processes engaged during intentional recognition rather than those elicited by unintentional recognition. Hence, the ERP results also suggest that the biasing influence of distractors does not relate to participants subjective experience of response conflict and may therefore be occurring outside of awareness.

Further, retrieval monitoring processing indexed by LPN was also explored as a function of confidence judgements, which revealed three important results concerning the LPN. Firstly, LPN was more negative in the late than early time-window for high confidence decisions. This indicates that retrieval monitoring was engaged more between 1000ms and 1500ms than 500 to 1000ms for in high confidence decisions, whereas there was no difference in early and late time windows for low confidence judgements, suggesting that low confidence judgements elicited retrieval monitoring in a more sustained manner. Second, the LPN was more negative across the left parieto-occipital location and in the late time-window for high confidence decisions to new targets. Herron (2007) argued that some aspects of the LPN are not related to response monitoring but rather are related to a search for episodic features and maintenance of the retrieved information. Thus, in the current study, the LPN for high confidence old targets may be due to maintenance of retrieved information rather than retrieval/response monitoring (see also Curran, et al., 2007; de Chastelaine, Friedman, & Cycowicz, 2007; Herron, 2007; Johansson & Mecklinger, 2003; Mecklinger, 2000). Third, in line with previous findings (Chapter 3 and Bergström et al., 2016), old distractors elicited a larger LPN than new distractors, but a novel finding was that this distractor-related LPN was more pronounced in the late compared to early time window for high confidence judgements. This finding is especially important as it suggests that unintentional recognition of distractors elicited enhanced retrieval monitoring when the judgements were made with high confidence, which is the opposite of what we predicted. One possible explanation for this pattern could be formed by considering the ERP results all together. Recollected old targets (only old targets elicited a parietal old/new effect) lead to higher confidence judgements (the parietal positivity was larger for high than low confidence), however, in this situation familiarity to old distractors (indexed by FN400), lead participants to engage in more retrieval monitoring as it required them to evaluate and monitor signals arising from two different stimuli. In contrast, for low confident responses old stimuli were associated with less recollection, and thus the total amount of information to monitor was lower for these trials than the high confidence trials.

Conclusions

Two experiments presented above aimed to determine the behavioural and neural correlates of spontaneous recognition in relation to high and low confidence intentional recognition judgements. The main finding of this research is that judgement confidence does not seem to be related to the influence of unintentional recognition of distractors on target recognition. Both behavioural results from two experiments and the ERP results support that assessment. Therefore, this research showed that participants' subjective experience of recognition confidence was solely related to target decisions, not to distractor processing, suggesting that distractors biased participants' responses outside of awareness and regardless of target memory strength. Another novel finding of this research was to show that retrieval monitoring was engaged for the high confidence recognition decisions when those were given in the face of simultaneous unintentional recognition of distracting information.

Chapter 5: General Discussion

This thesis investigated the distractor bias on intentional target recognition created by unintentional recognition of to-be ignored information that aimed to explore the SR effect under conditions of working memory load, and subjective confidence levels. The first chapter provided a general review of the related concepts such as recognition memory, working memory and confidence judgements all of which were of interest in this thesis. Previous research on SR has consistently shown that unintentional recognition of distractor biases target recognition especially when attentional resources are depleted with a secondary task (Ste-Marie & Jacoby, 1993) and that the SR effect originated from the dissociable intentional and unintentional neural processes (Bergström et al., 2016). In addition, recognition accuracy deteriorates with the influence of distractor bias in older adults, whereas young adults show this bias only when the secondary task demands substantial amount of attention (Anderson et al., 2011).

The first research used the memory Stroop task to investigate the role of dividing attention on the SR effect (Anderson et al., 2011). Specifically, experiment 2 compared the SR effect of young adults in divided and full attention conditions. Half of the participants engaged in a secondary task whereas the other half did not attend to a secondary task at all. Yet, the secondary task they used required WM resources as participants had to maintain the several digits and their respective order. Similarly, (Bergström, et al., 2016), used a secondary task that demanded subvocal rehearsal of a string of digits and required responding to a related probe digit that uses WM to maintain and recall a particular piece of information from the rehearsed string of digits. Still, the researchers failed to test how WM load would modulate the SR effect. Nevertheless, there is substantial evidence validating that working memory is involved in distractor processing and that it employs several functions such as attentional control (Berti & Schröger, 2003) and proactive control (Braver, 2012) to avoid unwanted distractor biases. Therefore, the role of WM on SR effect remains unanswered in the literature. Initially, this thesis aimed to explore the role of WM on SR effect and fill the gap in the literature. In doing so, in contrast to the Anderson et al. (2011) study participants across the herein presented studies, were constantly engaged in a WM task with different WM load conditions (either low or high).

The purpose of Chapter 2 was to address the involvement of working memory via manipulating the load on the secondary task. The design aimed to provide a wider understanding of the process underlining SR and whether or not other memory processes are involved in the distractor effect. Experiment 1 aimed to replicate the previous results on the SR effect with a similar methodological approach to (Anderson, et al., 2011). The memory Stroop task was used to measure distractor effect which was indicated by the difference of target recognition accuracy in the presence of previously studied and not studied distractor items. The results of the experiments reported in Chapter 2 indicated reduced target accuracy when the target and the distractor were congruent (old-old or new-new) compared to incongruent (old-new or new-old). These findings converge with the previous research (Anderson, et al., 2011; Bergström, et al., 2016). Additionally, experiments presented in Chapter 2 measured and compared recognition accuracy under the divided attention conditions with high and low working memory load. The distractor effect was observed when the attention was divided with a secondary task that heavily demanded working memory resources. By contrast, the SR effect was absent when the secondary task was less demanding. Importantly, the difference in the presence of the SR effect when the secondary task was low WM load compared to high WM load highlights that attentional processes cannot fully explain the causes of the SR effect. The influence of the secondary WM task was not limited to the WM load. Interestingly, the findings also indicated that the congruency in the n-back task (match-mismatch trials) can influence the SR effect; unintentional recognition of distractors biased target recognition in match trials but not in mismatch trials. This difference in SR effect suggests that there might be overlapping recognition processes in n-back task and memory Stroop task. The results indicated that the SR effect was more likely to be observed when the previous secondary task trial required a match response, this was especially observed in high episodic memory load. This finding can be explained by the involvement of the n-back task with recognition memory as well as working memory as suggested in previous research (Jaeggi, et al., 2010). In the n-back task, decisions would be made by comparing current and n-back trial, in the case of a match situation, familiarity would help the decision. Familiarity encourages a match response whereas a mismatch trial does not have the advantage of the familiarity. As such, automatic familiarity to match trials and the distractor bias in the memory Stroop task possibly compete for the resources of unintentional recognition. Moreover, the congruency of n-back trials did not interact with WM load, suggesting that the different working memory processes such as maintenance and shifting did not influence congruency of n-back task. This suggests that the SR effect is mainly influenced by the recognition processes underlying the n-back task.

Furthermore, sequential dependencies of SR effect were explored with the data of experiment 1. The findings were especially informative since this has not yet been reported before. Main findings on sequential dependencies revealed that previous targets and distractor pairs altered how the SR effect would occur. If the previous pair was an incongruent pair (old target- new distractor), then SR effect was more likely to occur. This suggests that there is a lingering influence of unintentional recognition as well as an immediate distractor bias.

Finally, experiment 2 investigated the influence of emotional working memory on SR effect. Specifically, the stimuli in the secondary WM task were replaced with emotional (positive and negative) and non-emotional realistic, colourful pictures from IAPS. The aim of doing this was (a) to explore the influence of emotions on the SR effect, and (b) to use emotional stimuli to manipulate the attention allocated for the secondary task. The results showed that when the secondary task contained negative emotional stimuli, only target recognition was affected. SR effect remained unaffected in all emotional conditions suggesting that emotions do not influence attention and/or resources allocated to avoid the unintentional recognition of the distractors. This finding compliments the results of (Bergström, et al., 2016) where emotional pictures were used as distractors. The authors failed to find any differences between emotional conditions therefore they combined all the emotional conditions. This was also replicated in experiment 3 of chapter 3 as we used the same stimuli and could not find an influence of emotion on SR effect.

Considered together, the findings from Chapter 2 reflect a high replicability of SR effect in young adults. The results also have shown that in order to avoid the unwanted SR effect WM resources are needed. The SR effect does not only rely on attentional resources but also WM. These two main findings contribute to the literature by establishing the influence of unintentional recognition on intentional recognition. As a novel contribution, Chapter 2 demonstrated that the influence of unintentional recognition is not limited to the current conflict, but also depends on previous task conflict (sequential dependencies) and the concurrent recognition (n-back congruency).

Chapter 3 sought to address the neural processes underlying the distractor effect when the secondary task included high and low working memory load conditions. The main aim was to replicate the results of (Bergström, et al., 2016), and extend their results by investigating the neural correlates of the influence of WM load on the SR effect. In addition, chapter 3 investigated the distractor effect using the same methodology used by (Bergström, et al., 2016). Behavioural results showed that participants were more likely to claim to recognise old targets paired with previously seen distractors compared to not-seen distractors. However, this response bias was equivalent irrespective of the working memory load. Moreover, the findings on the neural processes underlying the SR effect were replicated (Bergström, et al., 2016). Both targets and distractors elicited familiarity-related ERPs, whereas only target recognition elicited the ERP marker of conscious recollection. The results on ERPs are in line with the previous research supporting the view that familiarity and recollection are dissociable recognition processes (Rugg & Curran, 2007). The novel finding of experiment 3 was related to the early effect of the working memory load on the FN400 familiarity effect. As research has shown that prefrontal areas are recruited during WM processes, it is arguable that the difference found in the FN400 for high and low WM conditions are due to an overlap between recognition and WM. Extending the findings on LPN related to SR effect, the results also demonstrated that old distractors elicited more retrieval monitoring, suggesting a detection of the conflict.

The four experiments presented in Chapters 2 and 3 indicate that the influence of WM on SR effect can be observed both behaviourally and neurally. Findings from experiment 3 indicate that the SR effect stems from the familiarity to distractors. Although participants are instructed not to pay any attention to the distractors, they continued to process them along with the target information. Next, the unintentional familiarity (presence of previously seen distractor) made participants more likely to respond ‘old’, forming the SR effect. In an attempt to resist distractor bias, proactive control might have been engaged during the early stages of recognition to avoid distractor bias. However, given that depleted WM resources do not allow proactive control to be fully functional, the SR effect was only seen when participants were engaged in a secondary task with a high WM load. Additionally, retrieval monitoring indexed by LPN found for old distractors, also suggests a reactive control driven by the conflict.

In Chapter 2, results from experiment 1 showed the modulatory effect of WM on SR effect. However, WM didn’t affect distractor processing in experiment 3. Superficially, it seems that the influence of the WM could not be replicated in experiment 3. A direct comparison of the experiments was not possible because of the differences in the designs, yet several reasons could be suggested which may explain such differences. First, the secondary task used for experiment 1 was different than experiment 3. Although both secondary tasks were established as tasks that tap into WM processes, they might rely on slightly different processes. Second, the n-back task used in experiment 1 was interleaved with the memory Stroop task and therefore functioned in a more sustained manner, on the other hand, the WM task from experiment 3 required participants to rehearse a string of numbers and may be more prone to decay in the course of time (participants rehearsed strings from 4 to 6 trials that are randomly determined). Third, the low load condition of the WM task used in experiment 3 required no rehearsal, engaging almost no WM. Therefore, it is fair to say that the low load conditions from different WM tasks were hardly comparable. Across all experiments pictures were used as distractors and the words were used as targets. On the other hand, simple black and white drawings were used as distractors in Experiment 1, but colourful emotional photographs were used as distractors in experiment 3. Although, the emotional stimuli did not influence the SR effect, it may have created an attentional advantage because of their salience. The photographs used in experiment 4 may have been too salient so that the participants couldn't withdraw their attention from them despite to the concurrent WM task. A similar effect was reported in earlier studies on the SR effect. The SR effect was only observed when the targets were words and distractors were pictures, but not vice versa (Anderson, et al., 2011; Bergström, et al., 2016). The authors suggested that this might stem from the differences in the saliency of targets and distractors. A salient distractor would more likely to be perceptually processed and therefore attract more attention compared to a non-salient distractor.

Following this, the focus of the thesis moved from investigating the role of WM on SR effect to exploring the consciousness in the distractor bias. The aim of Chapter 4 was to address the influence of subjective confidence across two experiments. Those two experiments sought to answer the question: are people aware of the interference created by distractors. To investigate this, experiment 4 compared high and low confidence decisions across different target and distractor pairs and using ERP measures. Overall, experiment 4 revealed three important results. A late posterior negativity, which may be related to post-retrieval response monitoring (Johansson & Mecklinger, 2003), was modulated by high confidence judgements, although LPN for low confidence judgements was sustained from 500 to 1500ms. The novel finding of experiment 4 was that LPN was more pronounced for new targets in the late compared to early time window for high confidence judgements. Moreover, old distractors elicited more negative LPN which suggests that unintentional recognition of distractors produced enhanced retrieval monitoring when the judgements were made with high confidence. However, the SR effect did not show any relationship with participants' subjective experience of confidence for their target recognition judgements. However, experiment 4 failed to replicate the findings from experiment 3 on the LPN differences for target, distractor type and the interaction of target and distractor. The possible explanation might be the type of response requirements between experiments. In experiment 4 participants were asked to respond on their confidence judgements 2000ms after the presentation of the word-picture pair. This type of response was absent in experiment 3 as it did not include confidence judgements with the recognition response.

Considered together, the findings in this thesis reflect that the processing of the distractors results in unintentional recognition which then influences the intentional recognition of targets. This effect was particularly observed when the working memory was loaded, and previously encountered with a conflict. Furthermore, emotions do not seem to enhance or deteriorate the SR effect, as well as having a high or low confidence judgement on the recognition decisions.

Interpretation of the findings across studies

One consistent finding throughout the reported experiments was that the SR effect can be replicated with various stimuli and different secondary tasks that taps onto WM resources. Overall, three main methodological differences were presented in this thesis. First, except from experiment 3, all experiments contained black and white drawings as distractors in memory Stroop task. Experiment 3 was a close replication of Bergström et al. (2016), so the distractor stimuli were the emotional and non-emotional coloured photographs. Second, experiment 4 required participants to evaluate their confidence judgements. Third, experiment 2 used emotional and non-emotional coloured photographs in WM task as opposed to digits that were used in all other experiments. Nevertheless, SR effect was observed and replicated consistently in all experiments.

This thesis explored the modulators of SR effect with various constructs including WM, emotions and confidence levels and sequential dependencies of previous trials as well as the match and mismatch responses given to the n-back task. Chapter 2 found that concurrent high working memory load manipulated by n-back task enabled the SR effect to break through. In contrast, with a different working memory manipulation (chapter 3) SR effect was similar for both high and low WM loads. Differences in the saliency of distractor stimuli was suggested to account for such differences however future research should attempt to experimentally manipulate the distractor salience in order for its effects to be clarified.

Working memory effect was clearly illustrated in Experiment 1. However, experiment 3 and pilot study of the experiment 4 did not reveal any working memory influence on behavioural measurements. Several reasons might influence the results.

First, there were several differences in stimuli between experiment 1 and pilot of experiment 4 as highlighted above. Second, asking participants to evaluate their confidence levels might create an additional WM load. Confidence judgements are commonly used for determining an individual's belief that the information retrieved from memory is accurate and it is assumed that confidence reflects memory strength, especially in studies that use signal detection theory and receiver-operating characteristics (ROC) (Yonelinas, 1994). However, making a confidence judgement also involves other cognitive processes. One should make a decision and compare the decision with the criterion and monitor the retrieval of the final response. Retrieval attempt must be evaluated in order to select an appropriate response, as in tests of source memory (Henson, Shallice, & Dolan, 1999; Rugg et al., 2003; Wilding, 1999; Wilding and Rugg, 1996, Wilding and Rugg, 1997a) or when the information derived from a retrieval attempt is impoverished, leading to uncertainty whether retrieval has been successful (Henson et al., 2000; Henson, Rugg, Shallice, Josephs, & Dolan, 1999; Rugg et al., 2000, Rugg et al., 2002, Ullsperger et al., 2000). As such, Chua et al. (2006) found greater activation of medial and lateral parietal during confidence assessment compared to recognition, suggesting that these regions may play a specific role in the process of post-retrieval memory monitoring. Further, Henson et al (2000) found greater activation of right dorsolateral prefrontal cortex for low than high confidence judgements related to episodic retrieval reflects the degree of retrieval monitoring.

Another important finding regarding WM sub-systems could be discussed by comparing experiments 1 and 2 in the frame of Baddeley's multi component WM model. Experiment 1 used a WM task including digits that employed phonological loop whereas experiment 2 used a WM task including pictures that employs visuospatial sketchpad sub-system. Stimuli from WM task was shared with target stimuli in experiment 1 in contrast, it was shared with distractor stimuli in experiment 2. Nevertheless, secondary task (specifically 2-back task) divided attention to reveal SR effect in both experiments.

The aim of this thesis was not to test recognition models however the results have been interpreted in the context of dual process of recognition memory models. Especially, ERP findings indicated two distinct recognition processes involved in target and distractor recognition. Accordingly, Tulving's model postulates recognition responses involve auto-noetic awareness (remember/recollection) or noetic awareness (know/familiarity) or a combination of both; ERPs (experiment 3) indicated that target recognition triggered recollection and familiarity whereas distractor recognition triggered only familiarity. This further illustrates the automatic nature of unintentional distractor processing (Jacoby, 1993). This can also be linked with the results on experiment 4 where target recognition was found to be related with confidence judgements; accuracy in old target recognition was higher than new target recognition for high confidence judgements qualified by more positive LPC-recollection index on ERPs.

In memory Stroop task, the idea of the distraction effect stems from stimulus driven bottom-up processes. Salient distractor items attract the attention and enabled automatic memory search for the distractors as well as target items regardless from WM load (experiment 3). Therefore, memory signals coming from distractor items (as indexed by ERPs) biased the memory signals for target items. Further, Soto et al. (2005) argued that active maintenance of an irrelevant item in WM can elicit a bias to deploy attention, top-down effect can also occur in early onset. The results of experiment 3 in this thesis (the difference of FN400 in high and low WM load conditions) highlighted possible top-down influence of distraction which supports proactive account of dual mechanisms of cognitive control theory (Braver, 2012).

Limitations

Broad research on WM, attention and distraction has shown that the SR effect should be modulated by the latter factors. However, the work presented in this thesis did not address the influence of the WM sub-processes, focus of attention and the saliency of the distractors may have on the SR effect. Nevertheless, future research should include investigations on these constructs. For example, research showed that the SR effect only emerges when targets were words and distractors were pictures but not vice versa. Researchers argued that salient picture distractors may have been more likely to elicit unintentional recognition than words because they are more likely to attract attention. Alternatively, in Bergström (2016) et al. suggested that the secondary verbal WM task they used may have interfered more with their word processing than their picture processing. Similarly, in experiment 3 (see chapter 3). I found the SR effect even in low load condition suggesting that highly salient pictures alone (detailed, colourful and emotional) can be a strong trigger of unintentional recognition.

Experiment 1 (chapter 2) was a close replication of Anderson et al.'s study. However, in our examination new factors were introduced including episodic load and congruity lead to more complicated analysis (a 5-way ANOVA) which reduced the statistical power. For example, the added congruity factor was tested as a within subjects factor which greatly reduced the amount of trials per condition. Increasing the amount of trials could potentially account for a higher statistical power. However, this would require longer testing times, leading participants to feel fatigued towards the end of the experimental session. An alternative solution would have been to increase the sample size that would generate higher statistical power.

Targeted analysis was used to investigate recollection and familiarity using EEG. Although a substantial amount of research has shown that specific electrodes reflect recollection and familiarity, other cognitive processes that are related to the SR effect might have been overlooked. To account for this, Bergström et al. (2016) used partial least squares (PLS) analysis which correlates electrical activity in all electrodes and provides information on distributed patterns of spatial and temporal dependencies in the ERP data with minimal assumptions regarding the timing and distribution of potential effects. Targeted analysis conducted on ERPs limited the exploration of the SR effect in this thesis. Future research, should attempt to use PLS analysis to explore the neural activity underlining the SR effect.

Implications and future directions

The experiments reported in this thesis investigated the role of working memory on the occurrence of the SR effect. The first experiment demonstrated that concurrent task with a high working memory load increased the likelihood of the SR effect. This finding is in line with the load theory of selective attention and cognitive control that put forward by (Lavie, et al., 2004). According to Lavie and colleagues (2004) with high perceptual load, the distractor interference is expected to be reduced and with increasing cognitive load the distractor interference is expected to be increased. Experiments reported in this thesis consistently used a cognitive load and low perceptual load, as the memory Stroop task included only one target and one distractor stimulus. In the situations of low perceptual load, distractors may still be perceived. The cognitive control would ensure that focus is on goal-related stimuli.

Hence, findings on the role of WM load on the SR effect can be explained on the basis of the load theory of selective attention and cognitive control. Future investigations on the SR effect might be extended by testing the predictions of this theory on perceptual load. In turn, a distinction between the two mechanisms of selective attention could be made for SR effect. It could be predicted that the high perceptual load on the memory Stroop task might reduce the distractor processing and may produce SR effect despite the concurrent working memory load. At the same time, the early and late selection mechanisms may compete as the cognitive load and the perceptual load increased.

This thesis examined the role of WM on the SR effect with the lack of thorough investigation on the role of specific working memory sub-systems. It has been found (experiment 1) that the contribution of the WM on SR effect is related to the shifting, maintenance and updating sub-processes of working memory as 2-back task required these specific processes. More specifically, different type of tasks that measures or manipulates specific WM sub-processes might be employed as a secondary task. Furthermore, the findings showed that the SR effect occurred only after the match trials of the concurrent n-back task. In chapter 2, it has been argued that this might stem from the recognition used by the n-back task, still more research is needed for confirmation. Moreover, response congruency might be another factor that influences the SR effect. However, the insufficient amount of trials refrained the research to further explore the data on this issue. This might be addressed in the future research.

The differences in findings of WM load across studies suggest that the SR effect can be influenced by task used to divide attention and manipulate the WM load. This suggests that the occurrence of the SR effect is very sensitive to the nature of the secondary task. Further, working memory is a cognitive construct which relies on several cognitive sub-processes at the same time. WM measures and manipulation varies widely in the literature and each task taps onto different sub-processes. Therefore, the WM manipulation might have different results with different tasks. This thesis did not focus on the influence of sub-processes of the WM on the SR effect thoroughly. Thus, future research investigating different sub-processes would contribute in the understanding the influence of WM on the SR effect.

Furthermore, individual differences in attention regulation and working memory capacity (WMC) could potentially influence the SR effect. Especially, WMC has been linked to successful avoidance from distraction (Conway, et al., 2001). As an alternative to WM load manipulation, it is also possible to investigate the individual differences in WMC. This would be more informative on the general picture of the SR effect, since the WMC measurements (complex span tasks) are argued to measure WM more extensively especially compared to single span tasks (e.g. n-back task). WMC is defined by Kane and Engle (2002) as the capability of the executive-attention (maintenance of memory representations actively in the state of interference, which are reflected with action plans, goals and task-relevant stimuli) component of the WM system. Individual differences in the executive attention may also reflect in the capacity to prevent the diversion of focus from the distractors. For example, low WM span individuals are found to be more susceptible to interference than high WM span individuals (Conway & Engle, 1994; Conway, et al., 2005; Kane & Engle, 2002). Limited executive attentional ability in low spans lead them to rely more on automatic responses whereas high spans rely more on attentional processing. If that is the case SR effect would be larger for low span individuals compared to high span individuals since SR effect stems from familiarity to distractors which is thought to be an automatic process.

Finally, the role of retrieval processes indexed by the LPN need to be investigated in terms of time windows and the hemispheric location to further understand the SR effect. The experiments conducted in this thesis employed ERPs and revealed that participants probably monitored their retrieval after a detection of an old distractor. This was enhanced more when the new targets were paired with the old distractors.

Experiment 3 and 4 showed intentional recognition of targets and unintentional recognition of distractors can be dissociated with ERP measures. Although, the effect of WM on neural processes was not clear the results indicated that targets trigger recollection and familiarity related ERPs whilst distractors trigger only familiarity ERPs. This replicated Bergström et al. (2016) findings on ERPs, suggesting the recognition of targets and distractors in the memory Stroop paradigm is a reliable neural measure of SR effect. In forensic settings, discrimination of unintentional recognition of peripheral stimuli (distractors in memory Stroop context) from target recognition even without an accurate response, could have been useful in the search of the criminal evidence.

Distraction has been related to negative experiences, however, the distraction in SR effect is somewhat different than those on flanker tasks and negative priming research. General influence of SR is that the oldness (old or new) of distractor encourage participants to endorse the target item as ‘old’ or ‘new’. In the case of old target, recognition receives a boost from old distractors and leads to a correct recognition judgement. For new targets, new distractors create the same effect. Furthermore, in educational settings, identifying the influence of unintentional recognition on intentional recognition could have been used to develop more successful measurements of acquired knowledge. However, further research is required to make such claims.

Conclusion

This thesis explored the influence of the unintentional recognition of distractors on intentional recognition of targets. More specifically, the comparison of the influence of the seen or not-seen distractors on the recognition of old and new targets has been made and the difference is termed the SR effect. Previous research showed that dividing attention increased the likelihood of observing SR effect (Anderson, et al., 2011; Ste-Marie & Jacoby, 1993) and this stems from the familiarity to distractors (Bergström, et al., 2016). This thesis focused on the replication and the extension of the previous research to establish the SR effect. In addition to the replication, the results of the experiments (experiments 1 and 2) demonstrated the involvement of WM possibly by employing proactive control at the early stages of the recognition (experiment 3). Furthermore, conscious awareness of the unintentional recognition has been questioned by employing subjective confidence levels and revealed that the confidence judgements only affect intentional target decisions (experiment 4). Thus, the unintentional recognition does not go unnoticed by the cognitive system as it activates the retrieval monitoring when the distractors were encoded before.

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