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EXPLORING THE FATE OF NO LONGER RELEVANT SPATIAL INFORMATION USING A MODIFIED STERNBERG TASK

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EXPLORING THE FATE OF NO LONGER RELEVANT SPATIAL INFORMATION USING A MODIFIED STERNBERG TASK

by

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"Everything is illuminated in the light of the past." (J. Safran-Foer).

AUTHOR'S DECLARATION

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(1) INTRODUCTION

Forgetting, the breakdown of memory, is often associated with inconveniences in everyday life when the car key has been left on the kitchen table or when a phone number will simply not come to mind. However, forgetting has its justified and valued place in cognition. Forgetting allows us to remember the place where we parked our car today, rather than two weeks ago, it enables us to update previously incorrect information in our memory, and it gives us the opportunity to move on from unpleasant past experiences.

The origins of research investigating forgetting can be traced back as far as Ebbinghaus (1885), who found that the ability to recall a word list decreased the longer the interval of time since the list was originally learned. Since then, many studies have attempted to discover the causes underlying involuntary forgetting, both in the short-term as well as the long-term. Research by Peterson and Peterson (1959), for example, brought forward the trace decay theory, suggesting that, at least in the short-term, memories leave traces that decay in time unless they are rehearsed continuously. Others (e.g., Bower, Thompson-Schill & Tulving, 1995; Jacoby, Debner & Hay, 2001; Postman & Underwood, 1973) have argued that target material is forgotten because other material interferes with it. This can either be information learned earlier (proactive interference), or subsequently (retroactive interference). Forgetting in long-term memory has primarily been described as being cue-dependent. In other words, whether information once stored in long-term memory can still be accessed relies on the availability of appropriate cues to access it (Tulving, 1979; Tulving & Psotka, 1971).

A further branch in forgetting research has focused on the deliberate attempt to forget information (e.g. Bjork, 1989). The studies reported in this thesis fall into this area, since they explore mechanisms and factors involved in the directed forgetting (defined as the deliberate attempt to remove no longer relevant information from memory) of nonverbal information. Even though directed forgetting has enjoyed a considerable amount of interest in the verbal memory domain, only two studies have previously analysed its processes with nonverbal material. Attempting to fill this gap in the literature seems justified on a number of theoretical grounds. First of all, it may broaden our understanding of the functional characteristics of nonverbal memory, a domain that for a long time has received much less attention than verbal memory. Importantly, the memory literature remains divided on the issue of the overall architecture of memory, with some supporting the view that memory is made up of subcomponents (including a separate verbal and nonverbal memory store), and others in favour of models that present memory as a single unitary system. A comparison of the results found in the studies reported here with those typically found in the verbal directed forgetting literature would provide further information for this debate.

The following sections provide an introduction to nonverbal memory, several views on its place in memory as a whole, followed by a review of previous verbal and nonverbal directed forgetting studies.

(1.1) Functional Characteristics of Nonverbal Memory

While it is generally agreed in the literature that nonverbal memory is a complex system entailing several distinct mechanisms, there is less consensus on the nature of such components (Pickering, 2001). Some authors have argued that nonverbal memory is dissociated into a passive storage system and an active rehearsal mechanism that manipulates and modifies nonverbal input (Logie, 1995; Vecchi, 1998; Vecchi & Cornoldi, 1999). Others (Pickering, Gathercole, Hall and

Lloyd; 2001) have suggested that different processes exist for the handling of static (objects) and dynamic visual input (motion patterns). The majority of studies, however, propose a visual ("what") versus spatial ("where") dissociation, whereby visual memory involves the identification of the properties of an object (e.g. colour, shape), and spatial memory involves location processing.

Indeed, there is ample evidence in favour of this view (Baddeley, 1999; Della Salla, Gray, Baddeley, Allamano & Wilson, 1999; Logie, 1995, Tresch, Sinnamon & Seamon, 1993). One of the earliest investigations into the dissociation of visual and spatial memory was conducted by Holmes (1919), who studied the impact of brain injuries suffered by a World War I veteran. He observed that while the patient was able to identify an object (visual memory), he was unable to pinpoint its location (spatial memory). This isolated effect on the patient's spatial memory was interpreted as evidence that spatial and visual memory are segregated. Since then, a number of modern neuropsychological investigations (e.g., Humphreys & Riddoch, 1987) have supported this view. For example, the literature reports cases where patients suffering from brain injuries such as damage to the temporal and occipital lobes (Farah, Hammond, Levine & Calvanio, 1988) were able to engage in tasks requiring spatial memory (locating objects), but failed on a visual memory task (e.g., recognising the colour or size or shape of an object). Research by Hecker and Mapperson (1997) suggests that spatial and visual memory tasks trigger activation in the mangocellular and parvocellular pathways, respectively. Spatial, but not visual memory can be disrupted by congruent spatial tapping (Pearson, Logie & Gilhooly, 1999; Zimmer, Speiser & Seidler, 2003, Experiment 2), eye (Postle, Idzikowski, Della Salla, Logie & Baddeley, 2006; Pearson & Sahraie, 2003) or limb movements (Quinn, 1991) - although it remains unclear whether this is due to a shift in spatial attention

(Pearson & Sahraie, 2003; Smyth & Scholey, 1994a) or an interference caused by the planning or execution of motor processes (Lawrence, Myerson, Oonk & Abrams, 2000; Logie, 1995).

One common feature of nonverbal memory as a whole, however, appears to be that the processing of visual (Jiang, Olson & Chung, 2000) and spatial information (De Lillo, 2004) is organised according to perceptual principles. Evidence for this will be discussed in more detail at a later stage, but briefly, Jiang et al. (2000) found that performance in a visual change detection task (participants needed to judge whether the colour of a target location in a matrix had changed) was enhanced if the visual context remains unaltered between study and test, suggesting that the visual information was encoded as a configuration, rather than separately. Furthermore, in a spatial memory task (reproducing a sequence of locations within a matrix), De Lillo (2004, see also Smyth and Scholey, 1994b) found that performance improved if the sequence was grouped into clusters that were clearly separated (but see Parmentier, Andrés, Elford & Jones, 2006). In addition, Kemps (1999, 2001) reported that memory for sequences of locations is negatively related to the complexity of the path between them (see also Parmentier, Elford & Maybery (2005), and Parmentier & Andrés (2006) for further evidence). Such findings support the view that nonverbal stimuli presented together are not encoded in isolation, but in configuration to one another.

(1.2) The Functional Segregation of Verbal and Nonverbal Memory

Alongside the ongoing research investigating the structure and processes involved in nonverbal memory, there is an additional debate regarding its place in the overall architecture of memory. Contributions to this issue can broadly be classified in two categories: Models according to which memory is a multi-component system, in which nonverbal memory represents one store alongside many others, and models that view memory as a single processing system in which the encoding and treatment of verbal and nonverbal material is based on comparable principals. The following section will contrast one major model from each category, and the evidence that the literature has provided for each of them.

(a) Baddeley's Multi-Component Model of Memory

For many years, Baddeley's modular approach to memory (Baddeley, 1999; Baddeley & Logie, 1999) has shaped and influenced the way in which many psychologists have reasoned about memory and developed research paradigms. According to Baddeley's view, memory is made up of several subcomponents: Long-term memory is separated from working memory, and working memory itself is subdivided into further modules: a verbal (phonological loop) and a nonverbal (visuo-spatial sketchpad) subcomponent, and an attention-monitoring system (central executive) communicating between long-term and working memory. More recently, Baddeley (2000) has added the episodic buffer to his model, a system thought to combine information from the phonological loop and visuo-spatial sketchpad into integrated representations. In this model, findings from nonverbal memory research regarding the dissociation of visual and spatial memory (see above) are interpreted as evidence for segregated subcomponents in the visuo-spatial sketchpad.

There is some support in the literature for the partitions that Baddeley identifies in his model. Behavioural studies show that verbal distraction tasks can affect performance on a verbal task only, but leave performance on a nonverbal memory task intact, whereas visual-spatial distractor tasks selectively disrupt visual-spatial tasks only (e.g. Baddeley, 1999, Baddeley & Logie, 1999). Logie, Zucco and Baddeley (1990, Experiment 2) measured performance in visual (square matrix patterns of increasing complexity) and verbal (random sequences of consonants) span tasks in the presence of concurrent spatial or verbal tasks. They found that the visual span task was disrupted more severely by the secondary spatial task than the verbal task, while the opposite was true for the verbal span task. In a study by Baddeley, Grant, Wight and Thompson (1975, reported in Baddeley, 1999), participants performed a spatial or verbal matrix task either on its own or in combination with a pursuit tracking task. They found that congruent tracking impaired performance more severely in the primary spatial than in the primary verbal task. Research by Logie (1986) indicates that using irrelevant speech as an auditory disruptor can hamper the learning of verbal material, but has little detrimental effect on visual learning (see also Baddeley & Lieberman, 1980; Logie, 1986). Jarrold and Baddeley (1997) found that children with Down's Syndrome had impaired verbal memory, but performed comparably to a healthy control group in a visual-spatial task. This was interpreted as evidence that the phonological loop is selectively affected by Down's Syndrome. Furthermore, Sperry (1974) suggested that processing of verbal and nonverbal memory occurs predominantly in the left and right hemisphere, respectively. In a similar vein, Smith and Jonides (1997) found that working memory processes subdivide along the same dimensions within the frontal cortex, with greater activation in the left frontal cortex in verbal working memory tasks, and in the right cortex when the participant carries out a visual-spatial task.

Nevertheless, there is an increasing body of research demonstrating that the distinction between verbal and nonverbal memory is perhaps not as clear-cut as Baddeley's model suggests. Kemps and Newson (2006; see also Jones, Farrand, Stuart & Morris, 1995) suggested that some of the dissociations between verbal and nonverbal memory found in previous research could in fact be accounted for by the use of methodologies that are not entirely comparable. For example, contrary to studies reporting (sometimes contradictory) modality-specific decreases in memory in aging (e.g. Fastenau, Denburg & Abeles, 1996; Jenkins, Myerson, Joerding & Hale, 2000), Kemps and Newson (2006) found that, provided the tasks are matched in terms of memory paradigm, familiarity of stimulus material and processing requirements, verbal and nonverbal memory diminished at comparable rates with age.

Furthermore, some studies have observed comparable performance patterns in verbal and nonverbal memory, suggesting that the underlying processes in the two modalities are based on similar principals. Initially, research indicated that nonverbal memory is characterised by recency effects (elevated accuracy on the last item of a list) only (e.g. Broadbent & Broadbent, 1981; Walker, Hitch & Duroe, 1993), while verbal memory typically exhibits a U-shaped performance pattern (e.g. Gupta, 2005). Since then, however, it has been suggested that this outcome was due to the use of spatial recognition tasks that do not require participants to retain order information (Jones et al., 1995). When a serial recall task is used, performance curves in serial nonverbal memory studies do show clear primacy and recency effects (Jones et al. 1995; Parmentier & Jones, 2000; Parmentier, King & Dennis, 2006; Smyth & Scholey, 1996).

In addition, both verbal and nonverbal memory appear to be aided by grouping the items into separate chunks (Maybery, Parmentier & Jones, 2002; Parmentier, Maybery & Jones, 2004), and, in contrast to previous findings, research by Jones et al. (1995) has shown that nonverbal memory can be disrupted by irrelevant speech or articulatory suppression, secondary tasks traditionally associated with verbal memory only. Neuropsychological studies have shown that a left/right dissociation of verbal and nonverbal memory exists only in the ventral, but not dorsal pre-frontal cortex (D'Esposito, Aguire, Zarahn, Ballard, Shin & Lease, 1998). A recent combined behavioural and neuroimaging study by Nystrom, Braver, Sabb, Delgado, Noll and Cohen (2000) was also unable to confirm a clear left/right hemisphere distinction in verbal and nonverbal memory processing. Instead, they found that the same cortical areas responded equally to increases in working memory load of both verbal and nonverbal stimuli and that there was not one single brain area specifically responsive to only one type of stimuli. Finally, using a visual and spatial n-back task in which a spatial (motion tracking) or verbal (yes/no syntactic attention task) distractor task was integrated, Postle, D'Esposito and Corkin (2005) found that the verbal secondary task was able to disrupt performance in the visual n-back task (even though it failed to have an impact on the spatial n-back task). These studies support the notion that on some levels, verbal and nonverbal memory are more closely associated than is assumed by the multi-component model.

Taken together, the evidence presented above has encouraged the development of theories that challenge the modular approach to memory and view memory as a unitary system instead. In such models, it is assumed that verbal and nonverbal materials are dealt with by the same system in which the rules governing the processing of an item vary depending on the properties of the stimulus. Indeed, such an approach would fit more comfortably with the observation that in everyday life, very few objects are purely verbal or nonverbal, and we are in fact very skilled and flexible at combining the verbal and nonverbal properties of a stimulus. Thus, it is perhaps less plausible to assume that the underlying mechanism for such tasks would involve a complex interaction between several cognitive subsystems. One approach in contrast to the multi-component model presented by Baddeley was offered recently by Oberauer (2001; 2002). His Focus of Attention model, an extension of a framework initially proposed by Cowan (1997; 1999), is introduced below.

(b) Oberauer's Focus of Attention Model

In Cowan's model (Cowan, 1997; 1999), working memory is regarded as an integrated part of long-term memory. Here, the term "working memory" refers to those traces in long-term memory that are currently activated. Among these activated traces, only a limited amount of chunks (approximately 3-5 at any one time) is available to awareness. Activated memory traces that are not within this awareness are also retrievable, at the cost of more elaborate and time-consuming retrieval processes.

Oberauer adopted this principal hierarchy and extended it with an additional component that he labelled the "focus of attention" (which should not be confused with the terminology in Cowan's model where the focus of attention refers to those items within the individual's awareness. In Oberauer's model (see Figure 1, page 23), this area is called the direct access region, see below). This was done to accommodate evidence found in his own research (Oberauer, 2002; 2003) and research conducted by Garavan (1998) suggesting that from those items that are currently available to awareness, an individual can only process one single item at any one time. Thus, Oberauer's model of working memory contains three components: The activated subset of long-term memory containing all memory traces that have received some activation, and within this activated subset, a limited amount of chunks that are currently in a state of increased availability for rehearsal and processing (the "direct access region"). Within the direct access region, only one item is available for processing at any one time, and thus, in the "focus of attention".

Oberauer (2002) proposed that these three components should not be viewed as structurally or anatomically distinct parts, but that they merely reflect functionally different states of memory representations in working memory. Importantly, this model does not contain any distinction between verbal and nonverbal stimuli. Within this framework, memory traces are linked to others sharing similar features, and if one memory trace is activated, neighbouring traces will pick up some of this activation as well. Consequently, some of the factors causing disruption in memory performance are thought to be "overwriting" (memory traces sharing features have a tendency to overwrite one another) and "crosstalk" (competition between memory representations during the selective retrieval of one at the exclusion of others; this applies only to the direct access region).

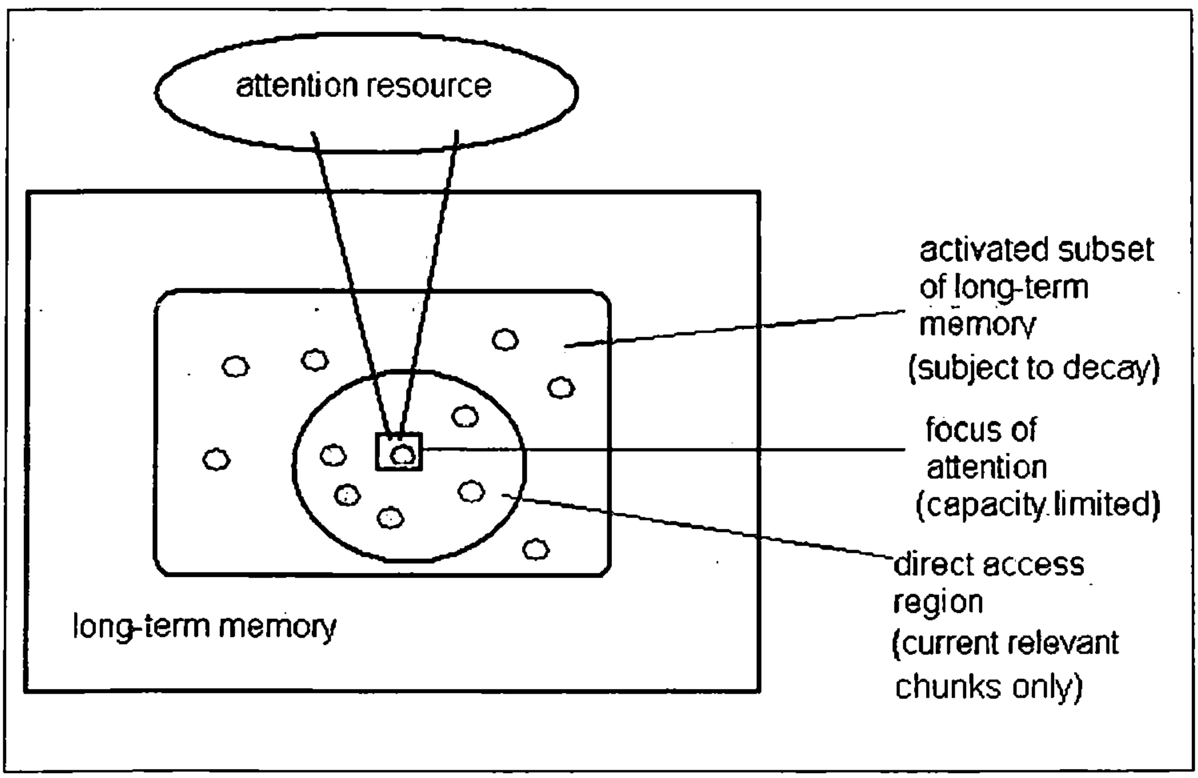

Figure 1: Oberauer's Focus of Attention Model

Until recently, research has provided inconclusive evidence for a tight interaction between working memory and long-term memory, leading some researchers to argue that working memory maintenance and long-term memory formation are in fact independent processes (e.g. Baddeley, 2000). Nevertheless, there is growing insight into the relationship between short-term and long-term memory. In an early study, Bower and Winzenz (1969) found that repeatedly using the same items in a short-term memory task gradually improves performance. The benefitial impact on performance was explained by the notion that the repeated items had been stored in long-term memory. Many neuropsychological studies have demonstrated that in a working memory task, the processing of familiar stimuli requires less complex brain mechanisms than the processing of novel stimuli: In an extensive review of previous research, Hasselmo and Stern (2006) proposed that while working memory for familiar information requires activity in the prefrontal and parietal regions only, novel information relies on mechanisms within the entorhinal and perirhinal as well as the prefrontal and parietal cortices. Research by Porier and Saint-Aubin (1995) found that serial recall of a word list was enhanced when the words were semantically related (compared to a word list containing semantically unrelated words), suggesting that the way in which the words were organised in long-term memory had an impact on recall. Hulme, Maughan and Brown (1991) compared short-term memory span for non-words versus words and Italian versus English words in English native speakers. They found that memory span was smaller for items that presumably did not reside in participants' long-term memory (i.e. Italian and non-words). In addition, Hulme et al. (1991) observed that teaching English participants the translated meaning of Italian words increased their ability to recall them relative to Italian words that had not been translated to them, suggesting that attaching the words with a lexical description increased long-term memory support (see also Hulme, Roodenrys, Brown & Mercer, 1995). Based on this, they argued for a model in which long-term memory has a direct impact on short-term memory (see also Gathercole, 1995).

A review of existing neuropsychological evidence by Fuster (1998) endorses this view. Fuster argued that working memory is made up of the temporary activation of a network of cortical neurons associated with long-term memory. According to this view, new memory is the outcome of the modification and rearrangement of old memory networks based on new experience. Randanath, Cohen and Brozinsky (2005) provided corroborating evidence for the notion that working memory maintenance contributes to long-term memory formation. Conducting an fMRI study, Randanath et al. (2005) found that in a simple recognition test, the delay between stimulus presentation and test is characterised by an activation shift in the brain from anterior to posterior regions during the early and late phases of the delay respectively. They thus argued that maintenance occurs in two stages – an early stage during which sensory information is decoded into an internal form that can be maintained in the absence of the stimulus, and a second stage in which maintenance of this information takes place relatively automatically (cf. Jolicœur & Dell'Acqua, 1998). They also found a correlation between activation in specific brain regions during the early phase of working memory and successful long-term memory retention: The activity in the left dorsolateral prefrontal cortex and the left anterior hippocampus was enhanced only with items that participants were able to remember well in a later recall task (i.e. items that had remained in long-term memory). Furthermore, they found that long-term memory of an item was impaired only if maintenance was disrupted at an early stage, rather than later on. Randanath et al.

(2005) interpreted these results as evidence that there is indeed a link between working memory and long-term memory, albeit not a linear one: The successful transfer of an item from short-term into long-term memory appears to occur relatively early on in the maintenance process, and any subsequent attempt to boost performance (e.g. increasing rehearsal time) is unlikely to result in better memory.

Taken together, such evidence supports Oberauer's and Cowan's notion of working memory as an integrated component of long-term memory.

1.3 Directed Forgetting in Verbal Memory

The previous section has shown that continued disagreement remains over the segregation of verbal and nonverbal memory. In order to contribute to this debate, and its implications for the overall architecture of memory, this thesis seeks to explore an area that (safe for a small number of studies, see below) previous research has neglected: Factors involved in our ability to ignore no longer relevant visuo-spatial material in memory. Until recently, the majority of studies looking at directed forgetting (the deliberate attempt to "forget" information) have used verbal stimuli. An exploration of its processes with visuo-spatial material could not only broaden our understanding of nonverbal memory, but also enable us to draw conclusions about any parallel forgetting mechanisms in verbal and nonverbal memory, thereby adding further evidence to resolve the dispute surrounding the potential separation of these two domains. If over the course of this thesis results emerge that are compatible with phenomena observed in verbal directed forgetting, this would provide evidence for a model in which memory is a single modality. Results that are at odds with those found with verbal stimuli would favour models that present memory as a multi-component system.

(a) The Cognitive Value of Forgetting

The fate of no longer relevant spatial information in memory

Even though most people would probably argue that memory failure is an undesired nuisance, the ability to forget information is nevertheless a crucial cognitive function. We live in a world in which we are permanently bombarded with large quantities of information, while our cognitive system is only able to handle a limited amount of stimuli at any one time. The ability to discard any input that is irrelevant to us at that particular moment is therefore imperative for healthy cognitive functioning.

Indeed, research in various areas of cognition such as visual and auditory perception, attention, and memory consistently shows that the ability to disregard irrelevant information is a critical component of successful performance. In attention research, for example, Tipper's negative priming paradigm (e.g. Tipper, 1985, see also Loula, Korutzi & Shiffrar, 2000; Milliken & Tipper, 1998) demonstrates that performance on relevant information is (at least in part, see also Milliken, Tipper & Weaver, 1994) facilitated by a selective suppression (or "inhibition") of task-irrelevant information. In a standard negative priming experiment, pairs of primes and probes are presented to participants. During the prime, participants respond to one item, but are told to ignore the other. The following trial (probe), involves a further pair of items where the target is either new, matches the item previously attended to, or matches the item participants were told to ignore in the previous trial. Performance is facilitated if the target matches the attended item in the prime. If, however, participants are subsequently presented with an item that they ignored during the priming phase, response times lengthen. This has been understood as evidence that in spite of the command to divert attention away from them, ignored items are nevertheless processed to some extent. Attention to these items is inhibited to enable superior performance on attended items (positive priming). Once an ignored item becomes the target of attention, a release from its inhibition must be accomplished before a response can be made (negative priming).

Ignoring information that is not goal-relevant is equally beneficial in memory performance. For example, younger adults' superior memory in comparison to that of older people is thought to be due to the latter's struggle to ignore irrelevant information, allowing those to intrude goal-relevant material (e.g. Andrés, Van der Linden & Parmentier, 2004; Oberauer, 2001; Zacks, Radvansky & Hasher, 1996). Similarly, people with high working-memory span appear to be more efficient at disregarding irrelevant stimuli than those with low working-memory span (Conway & Engle, 1994; Kane, Bleckley, Conway & Engle, 2001; Rosen & Engle, 1997).

The following pages will cover some of the main factors that influence the ability to disregard task-irrelevant information in memory, followed by a presentation of a recent account tapping into the underlying processes that govern such behaviour.

(b) Factors That Influence Successful Deliberate Forgetting

There is a growing body of research exploring elements that may have an impact on our ability to ignore no longer relevant memory traces. Such research has for the most part employed variations of Bjork's directed forgetting paradigm (e.g. Bjork, 1989; Johnson, 1994; MacLeod, 1998). In a standard directed forgetting experiment, participants learn two sets of items, and are subsequently instructed to "forget" one set. Costs and benefits of this instruction are measured in terms of accuracy and response latencies on items from both lists. With this methodology, research has identified a number of factors that affect our ability to deliberately ignore no longer relevant stimuli in memory.

(i) Encoding strength

One aspect influencing deliberate forgetting is the extent to which to-be-forgotten (TBF) stimuli have been encoded before the "forget" command is given (e.g. Basden, Basden & Gargano, 1993; Basden & Basden, 1996). If the cue to forget is delayed until an entire list of TBF words has been presented, participants' recall of TBF items is quite poor, while their memory of to-be-remembered (TBR) items is superior to a control group that studied the two lists without a "forget" instruction. Furthermore, the set size of the TBF list has no impact on overall performance (Bjork, 1989). These results suggest that the "forget" instruction impairs performance with TBF items, but this in turn helps facilitate performance with goal-relevant TBR material. However, when a cognitively less demanding recognition task is used, participants are still able to identify TBF items, suggesting that the corresponding memory traces were not entirely erased (Bjork, 1989; MacLeod, 1998).

If the "forget" instruction is given early on in the encoding process (e.g. where words are presented sequentially, each immediately followed by either a "remember" or "forget" instruction), TBF words can prime participants in a later word fragmentation task (MacLeod, 1998). Nevertheless, recognition and recall of TBF stimuli are both impaired in comparison to TBR stimuli, and participants are better at judging the serial position of a TBR than TBF item (Basden & Basden, 1996).

These results support the intuitive thought that longer encoding periods are associated with a stronger persistence of memory traces of items that the individual is trying to ignore. When the "forget" instruction occurs early on in the encoding process, performance with TBF material is impaired in both recall and recognition tests. If the instruction is delayed until the TBF material has been encoded and consolidated, signs of "forgetting" only surface in recall tasks, whilst leaving memory of the TBF stimuli preserved in recognition tests.

(ii) Relationship between TBR and TBF items

TBF items that have some relationship with TBR information (e.g. through semantics) are harder to ignore than irrelevant items that are unrelated to the relevant material. Golding, Long and MacLeod (1994) found that when words on the TBF and TBR list were semantically related (e.g. CRAB and LEG), participants were unable to selectively ignore the TBF word. This was not true if the TBF and TBR items were semantically unrelated. The ability of semantic relatedness to overwrite the "forget" instruction appears to be a function of age: Fifth grade children (Lehman, Srokowski, Hall, Renkey & Cruz, 2003) and elderly adults (Zacks et al., 1996) alike find it harder than younger adults to ignore words that were semantically related to those they had to remember.

(iii) Cue-Test Delay

The delay between the cue to forget a subset of material and the memory test (Cue-stimulus interval: CSI) plays an additional role in directed forgetting. Oberauer (2001) found that the prevalence of TBF memory traces declined over time, but he was still able to observe evidence for their presence after 5000 ms. Memory performance was only a function of TBF set size if the CSI was below 600 ms (see also Zacks et al., 1996, for converging findings). These results suggest that longer delays between forget instruction and memory test are associated with an increase in the success to forget the task-irrelevant material.

(iv) Ageing

The ability to selectively ignore information in memory appears to develop over childhood (Lehman et al., 2003) and deteriorate in later adulthood. Older adults' declining memory performance is often associated with an inefficient ability to disregard task-irrelevant information (e.g. Andrés et al., 2004; Oberauer, 2001; Zacks et al., 1996). Zacks et al. (1996) observed that in a directed forgetting task, both older and younger adults show signs of "forgetting" (impaired memory of TBF items accompanied by a superior recollection of TBR items), but that older adults remembered significantly more TBF items than younger adults do. This appeared to damage their performance – older adults performed poorer overall than younger adults (see also Oberauer, 2001, for similar results).

(c) Mechanisms Underlying Deliberate Forgetting

In addition to exploring factors influencing our ability to ignore irrelevant information in memory, research has also attempted to unravel some of the underlying processes. Some researchers attribute the diminished availability of TBF material to inhibitory mechanisms suppressing the activation of the corresponding memory traces (see, for example, Bjork, 1989; Johnson, 1994). Others have argued that the observed directed forgetting effects are merely the result of an attentional shift due to contextual change (e.g. Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002 - but see Whetstone, Cross and Whetstone, 1996). Recently, a further account was offered by Oberauer (2001), who refers to the Focus of Attention Model in an effort to integrate findings from his own directed forgetting research into a meaningful theoretical context. This makes Oberauer's account perhaps more prudent than others, and it is for this reason that my own work is primarily based on his studies. In this section, I will review some of Oberauer's main findings, followed by a discussion of his interpretation of the processes that govern deliberate forgetting.

(i) Oberauer's Intrusion Cost

Oberauer (2001) conducted a study using a modified version of the Sternberg task[1]. Participants (younger and older adults) studied two word lists presented to them simultaneously. Subsequently, a cue was given indicating which list was now no longer relevant. Participants were then probed with a word and asked to judge whether this was a word that they had to remember. There were three probe types – words from the TBR list, words from the TBF list, or new (control) words that had been in neither list. To respond correctly, participants needed to accept the probe if it was from the TBR list, and reject it if it had either been to-be-forgotten or new. Oberauer varied the set size of both lists (either 1 or 3 words), as well as the delay between cue to forget and probe presentation between 100 and 5000 ms.

Oberauer's primary interest was the comparison of response latencies between control and TBF probes. Comparable to previous research by Zacks et al. (1996), Oberauer found that overall, both younger and older adults took longer to reject a TBF than a control probe as not to-be-remembered. This "intrusion cost" was more pronounced within the older age group. Furthermore, Oberauer found that the set size of the TBF list only had an impact on performance until a CSI of 600 ms, and this applied to both age groups. Intrusion costs gradually diminished as CSIs increased, but were nevertheless still observable with both set sizes even after 5000 ms.

As indicated above, Oberauer interpreted these findings with reference to the Focus of Attention Model (Oberauer, 2001; 2002). In addition, because his task involved recognition memory, he also consulted a recent recognition model

[1] Sternberg (1966) explored response latency patterns in list memory by sequentially presenting a string of digits to participants, followed by a test period where they judged whether a target digit had been among the previously learned digits. He found that response times were a function of list size (longer response delays associated with longer lists), indicating a scanning process in which the entire list is searched before determining whether the probe matches an item in the list.

describing this process as involving two stages (e.g. Yonelinas, 1999). Oberauer's memory model has been discussed above, but in order to make complete sense of the interpretation of his data, it may first be useful to provide an introduction to the recognition theory on which some of his analysis is based.

(ii) The Dual Process Theory of Recognition

Successful recognition involves the ability to map an incoming stimulus onto a matching representation in memory and restore the context in which this stimulus has been encountered before. For example, in order to recognise a familiar person on the street, it is necessary to realise that this person has been met before, and to re-establish where and/or when this encounter had taken place. To accommodate this line of reasoning, the dual-process model of recognition (Mandler, 1980) encompasses two distinct processes: familiarity and recollection (e.g. Dobbins, Kroll, Yonelinas & Liu, 1998; Jacoby, 1991; Khoe, Kroll, Yonelinas, Dobbins & Knight, 2000; Mandler, 1980; Yonelinas, 1994, 1999; Yonelinas, Kroll, Dobbins, Lazzara & Knight, 1998).

The term familiarity refers to the process that establishes that a stimulus has been encountered before. The precise mechanism that leads to feelings of familiarity remains a subject for debate within the recognition literature. One proposal that has received considerable support through research was developed by Whittlesea and colleagues (e.g. Whittlesea, 1993). According to this theory, a never encountered item requires careful and elaborate processing. If this item is then repeatedly presented, it should be easier to process it once again because you have already done so previously. This ease in processing is, according to Whittlesea (1993), the source of the perceived feeling of familiarity. In this interpretation, it is not the long-term memory trace of the item itself that produces the familiarity, but the perceptual fluency with which we process the item that leads us to conclude that it must be "old". Whittlesea's interpretation of familiarity (and whether it can provide a better fit for the data in this thesis) will be discussed in more detail at a later stage (Series 2), but for now we will turn to a slightly different interpretation of the underlying origin of familiarity.

Oberauer's interpretation of the intrusion cost was based on the dual processing theory of recognition developed by Yonelinas (1999). Here, familiarity is not attributed to perceptual fluency. Instead, it is thought to be an automatic process reflecting the relative strength of the activation of the matching representation in memory (Yonelinas, 1999). Yonelinas (1994, 1999) reports that familiarity is best described along the lines of a signal-detection theory: If the stimulus resembles a representation in memory with an activation exceeding a threshold, it is judged to be "old". If the stimulus resembles a representation that is activated below the threshold, it is not possible to determine the previous occurrence of the item and it is judged as "new".

Thus, in contrast to Whittlesea's perceptual fluency approach to familiarity (Whittlesea, 1993), this theory argues that familiarity is not the product of the ease with which we process the item. Instead, familiarity is understood to involve a direct comparison of the incoming stimulus with what is already stored in long-term memory: If the properties of the stimulus map onto a sufficiently activated long-term memory representation, then it is possible to determine that this item had been encountered before. If, on the other hand, no long-term memory trace exists that represents an identical match to the stimulus, no familiarity signal is triggered. In other words, this theory places great importance on the existence of long-term memory representations that match the properties of the stimulus – a feature that will be of relevance for Oberauer's interpretation of the intrusion cost (see below).

To summarise, in Yonelinas' dual process theory of recognition, familiarity is thought to result from the existence of long-term memory representations matching the incoming stimuli. However, when he analysed receiver-operating characteristics (ROC) data in recognition memory, Yonelinas (1994) found that familiarity alone cannot be the sole underlying process in recognition. ROCs are defined as the function that relates the proportion of hit rates to the proportion of false alarms. Points on an ROC graph are plotted as a function of confidence. The interecept of a transformed ROC (d') provides a measure of discriminiability between hit and false alarm rates. Symmetrical ROC plots are perfectly described by a signal detection theory. If recognition is based on a simple familiarity judgment, and if familiarity is best described by signal detection theories, recognition data should yield perfectly symmetrical ROC plots with a slope of 1.0 (i.e. the most familiar item will yield the most confident response, the second most familiar item will yield the second most confident response etc.). However, this is not the case: in the literature, the ROC slope in recognition memory is slightly skewed, leading Yonelinas to propose that an additional process must contribute to recognition.

Recollection is thought to be a deliberate and conscious search process through which contextual information related to the stimulus is accessed on an all-or-none retrieval basis in order to correctly recognise the identity of the stimulus (e.g. Dobbins et al.; 1998; Mandler, 1980; Yonelinas, 1994, 1999). Evidence that recollection and familiarity both contribute to successful recognition has been found in behavioural (Dobbins et al., 1998; Jacoby, 1991; Yonelinas, 1994) as well as neuro-anatomical research (Khoe et al., 2000; Yonelinas et al., 1998, see also

Mandler, 1980, for a brief review of a number of older studies). Such research also suggests that familiarity and recollection are dissociated processes.

Khoe et al. (2000), for example, argued that amnesia is typically associated with a pronounced reduction in recollection, while familiarity remains preserved. Indeed, Mandler (1980) reported a number of studies showing that while amnesics have little trouble determining that an item has been encountered before (familiarity), they struggle to re-establish the context in which the item had been seen (recollection). Yonelinas and colleagues (1998) compared recognition memory ROC slopes of amnesic versus healthy participants and found that for the former, slopes were symmetrical (indicating a sole reliance on familiarity) and for the latter, slopes displayed the typical skewed pattern normally observed in the recognition literature (indicating a reliance on both familiarity and recollection). In behavioural research, studies have found that recollection, but not familiarity can be impaired by divided attention (Gardiner & Parkin, 1990), whilst Macken (2002) found that presenting an item within the same context in which it had been encountered earlier had a positive effect on recollection memory, but little impact on familiarity. Such results sit comfortably with the idea that familiarity and recollection are two separate processes.

(iii) Oberauer's Interpretation of the Intrusion Cost

Oberauer (2001) found that participants rejected a probe more slowly if it was a TBF, rather than a control (new) probe. Based on Yonelinas' (1999) theory of recognition outlined above (in which familiarity is thought to be the result of a successful comparison between the incoming stimuli and their matching activated representations in long-term memory), Oberauer argued that probes from both TBR and the TBF list would still have matching traces stored in long-term memory and therefore elicit strong familiarity signals, especially when the time interval between the presentation of cue and probe is short. Participants thus need to rely on recollection processes in order to determine in which context they had seen the probe previously. When participants study a TBF probe, the familiarity signal prompts them to judge the item as "old", thereby initially pushing them towards an incorrect response. In order to realise that this item had not been among the TBR list participants need to engage in elaborate recollection processes reinstating the context in which the TBF probe had been encountered earlier. Thus, rejecting a TBF probe is a more time-consuming process than rejecting an item that yields no familiarity signal at all (i.e., a new probe).

To summarise the previous point, Oberauer argued that the intrusion cost is evidence that TBF items are still represented by activated traces in memory. This activation is relatively long-lasting – in his own study, Oberauer observed an intrusion cost even 5000 ms after the cue to forget had been given. However, Oberauer also found evidence that TBF representations do not share the same status in memory as TBR items: Only the TBR set size affected overall performance. In order to make sense of this observation, Oberauer resorted to his Focus of Attention model of memory (see Figure 2, p. 56):

To recapitulate, in Oberauer's model, working memory forms an integrated part of long-term memory, in which memory traces can be in varying functional states depending on their activation and utility to the task. Only one item is processed at any one time in the Focus of Attention. Other activated representations that are currently task-relevant are held in direct access region, an area that is thought to be confined by capacity limits. Those items that are still activated, but no longer relevant to the task are stored in the activated subset of long-term memory. This region is not confined by capacity, but, if not transferred back into the direct access region at some point, representations in this area will gradually lose their activation.

Applying this model to his data, Oberauer argued that only the TBR items remain in the direct access region (and, by association, within conscious awareness). This enables the focus of attention to quickly capture the matching representation once a TBR probe is presented, resulting in a correct and speedy identification. A control probe is a previously unseen stimulus for which the participant has no matching activated trace in memory. It triggers no familiarity signal and is thus rejected quickly.

What is, however, the fate of the TBF set? Oberauer argued that TBF stimuli are not fully forgotten. The appearance of the intrusion cost suggests that the corresponding memory traces are still activated and, upon presenting a TBF probe, create a feeling of familiarity that the participant must overcome through conscious recollection in order to make the correct judgement that this item was not among the TBR set. Yet, because the TBF set has no influence on overall performance, this would rule out the possibility that, once the "forget" command has been given, the corresponding TBF representations continue to form a part of the capacity-limited direct access region. Oberauer proposes that instead, the "forget" cue initiates a process in which the TBF memory traces are moved into the activated subset of long-term memory, a modality unconstrained by capacity. Here, they initially remain sufficiently activated to still trigger a sense of familiarity. However, because they are not within immediate conscious awareness, the recollection of the context in which they had been encountered previously demands more effortful processing, resulting in longer response times. Oberauer found that the TBF set size had no impact on general performance if the delay between the cue to forget and probe presentation was larger than 600 ms. This suggests that it takes approximately 600 ms to remove the no longer relevant set from the direct access region.

A further outcome of Oberauer's study was that the magnitude of the intrusion cost decreased as the delay between cue to forget and probe presentation lengthened (although it never fully disappeared). According to Oberauer, this is because traces of the TBF material reside in the activated subset of long-term memory, where they decay with time in the absence of rehearsal. Due to this decreasing activation, the familiarity signal attached to a TBF probe decreases, making it less likely for an intrusion cost to occur.

In addition to being able to account for Oberauer's own results, his model can also explain other results from other directed forgetting studies. For example, the finding that the selective forgetting of TBF material is not possible if it is semantically related to TBR material (Golding et al., 1994) could be accounted for by overwriting – when memory traces share certain features with one another, then the activation of one trace will pass on some activation to related traces as well. Oberauer's model would interpret this data as evidence that any attempts to keep the TBR memory trace activated should make it difficult to reduce the activation of a related TBF trace.

Research has also found that memory for TBF items is particularly impaired if the "forget" cue has been given early on in the encoding process (e.g., Basden & Basden, 1996; Basden, Basden & Gargano, 1993). This would suggest that if participants do not have sufficient time to strengthen the memory trace of an item that is later declared irrelevant, the activation of this trace will fade away faster than one that has been rehearsed for a longer period of time (but see Randanath et al., 2005, who argued that increasing rehearsal time of an item has no influence on its availability later).

A competing interpretation of the intrusion cost is that it is the outcome of a source-discrimination problem: Perhaps, the reason why participants take longer to reject a TBF item is because they cannot dissociate between those activated memory representations that are to-be-remembered and those that are no longer relevant. However, this does not seem to be a plausible explanation: Oberauer observed faster response times to TBR probes than TBF probes. If participants were inclined to confuse the two lists, they should be cautious (and thus slow) in response to both TBR and TBF probes. Furthermore, he found that only the TBR set size affected performance, suggesting that TBR and TBF sets were processed in dissimilar ways. Research shows that older adults are particularly susceptible to deficits in source discrimination (e.g., Kliegl & Lindenberger, 1993). Thus, error rates should be particularly pronounced in the old age group compared to the young age group. This was not the case, however: Oberauer found no main effect of age, and performance differences between the three probe types were similar in both groups. Taken together, these results suggest that source discrimination is probably not a convincing account for the intrusion cost in verbal memory.

(1.4) Some Unresolved Issues

Oberauer (2001) interpreted the intrusion cost as evidence that traces of no longer relevant material remain activated in memory, thereby triggering a sense of familiarity if presented as a probe. This is a plausible interpretation considering that in his experiment, participants studied words from their everyday language. Such words should benefit from a stable repertory in long-term memory.

This, however, leaves a number of important questions unanswered: First of all, what is the fate of no longer relevant items that do not benefit from enduring long-term memory backup? This point ties in with a second issue worth exploring:

Oberauer's interpretation of the intrusion cost relies on the assumption that familiarity is triggered following a successful comparison of existing long-term memory traces with the TBF probes (see also Yonelinas, 1999). However, if items are not firmly anchored in long-term memory, perhaps any feelings of familiarity would not be triggered by mapping the incoming stimulus onto an existing memory representation, but by an assessment of perceptual fluency (i.e., the ease with which we can process the perceptual properties of the item due to its repeated presentation – cf. Whittlesea, 1993). One aim of this thesis was to explore this avenue in more detail.

A further question that this dissertation examined was whether an intrusion cost can also be observed with non-verbal stimuli. The following sections will give a brief introduction to each of the questions outlined above.

(a) The Involvement of Long-Term Memory

Oberauer's interpretation of the finding that TBF items are rejected more slowly than control items rests on the assumption that working memory is an integrated part of long-term memory, and that the intrusion cost only occurs because items already represented in long-term memory will only decay slowly when no longer rehearsed. In order to determine whether Oberauer's model offers a plausible explanation of the intrusion cost, it is useful to explore whether it can also anticipate the outcome of a study using items for which participants do not have existing stable long-term memory representations. Presumably, the model would predict that without such long-term memory backup, the activation of such an item should deteriorate quite rapidly once attention is moved away and rehearsal is ceased. Should this be the case, the re-presentation of a no longer relevant item at test should not trigger a feeling of familiarity, thereby making it indistinguishable from a new item. In such a scenario, an intrusion cost should not occur.

Examining whether no longer relevant memory traces decay more rapidly in the absence of long-term memory backup tests the view that long-term memory can have a direct impact on working memory performance. If the deliberate creation of long-term memory representations of the test items is successful and results in an intrusion cost, this would provide corroborating evidence for a model in which working memory forms a subcomponent of long-term memory. In contrast, such outcome would sit less comfortably with a model presenting working memory as a segregated modality from long-term memory (e.g., Baddeley, 1999; see above).

(b) The Nature of Familiarity in Oberauer's Intrusion Cost

As outlined earlier, the predictions discussed in the previous section rest on the assumption that familiarity occurs whenever an incoming stimulus is mapped onto a sufficiently activated long-term memory representation (Yonelinas, 1999). There is, however, an alternative explanation of familiarity, which argues that items are perceived to be old because their repeated presentation facilitates the processing of their properties. Such increased perceptual fluency would then presumably trigger a familiarity signal (Whittlesea, 1993).

Oberauer has not implemented this theory in his analysis, but the possibility arises that perhaps, the familiarity driving the intrusion cost is not in fact caused by resilient long-term memory representations, but simply by the repeated exposure to the test items, making it easier for participants to process them.

Such an interpretation would place less emphasis on an involvement of long-term memory. To recap, in the previous section, it was predicted that when a test item is only weakly represented in long-term memory, it would decay rapidly once the "forget" cue has been given. If the intrusion cost is driven by a familiarity that is produced by detecting a long-term memory representation that matches the properties of the stimulus, then no intrusion cost should occur, because the TBF item would no longer have a matching activated representation in memory.

On the other hand, if the type of familiarity underlying the intrusion cost was due to perceptual fluency (Whittlesea, 1993), then an intrusion cost should be detected regardless of the relative degree to which the TBF item is represented in long-term memory. In other words, TBF probes should always trigger a familiarity signal because they had already been processed earlier – irrespective of whether the item was sufficiently stored in long-term memory. This issue is explored in more detail in Series 2 of this thesis.

(c) Nonverbal Intrusion Costs

As indicated earlier, the literature remains divided on the functional segregation of verbal and nonverbal memory. Thus, exploring whether Oberauer's intrusion cost is a phenomenon that also extends to nonverbal memory may contribute to this debate.

In addition, up until fairly recently, visuo-spatial working memory research has revealed very little about the fate of no longer relevant information. At this stage, it is unknown whether no longer relevant nonverbal material leaves a gradually decaying memory trace that is able to trigger an intrusion cost in the same way as found with verbal stimuli. Carrying out a series of directed forgetting studies with nonverbal material may help close this gap in the literature.

Studies investigating the effect of irrelevant visual noise on memory performance have found some preliminary evidence indicating that once encoded, nonverbal memory representations remain activated for some time. For example, research by McConnell and Quinn (2000; Quinn & McConnell, 1996) demonstrated that irrelevant visual noise negatively interfered with participants' overall memory performance. Furthermore, in a recent priming study by Miliken, Tipper, Houghton and Lupianez (2000), it was found that irrelevant spatial locations can prime participants to identify them in a later recognition task. These studies suggest that, similarly to what has been found with verbal material (see above), irrelevant visuo-spatial information is processed partly automatically to some degree and cannot be erased from memory immediately, thereby still interfering with memory performance.

To the best of my knowledge, only two previous studies have explored the fate of no longer relevant nonverbal stimuli. Cornoldi & Mammarella (2006) used the selective visuospatial working memory task to explore if irrelevant locations can interfere with participants' ability to recall a specific target. Participants studied a series of three or four sequences of locations in a 4x4 matrix. Subsequently, they were required to point out the last location of each sequence, in the order in which the sequences had been presented (i.e., last location of sequence 1 followed by the last location of sequence 2 etc.). In line with the idea that irrelevant nonverbal material can remain activated in memory, Cornoldi and Mammarella found that participants were more likely to commit intrusions (erroneously identifying a no-target location) than invention errors (selecting a location that had not been presented in any of the sequences). This was also the case when they addressed some of the methodological limitations of their initial study (such as having unequal probabilities of committing an intrusion versus an invention error), and when they ruled out the possibility that intrusion errors may have been artificially created by participants only remembering the general area of a target (thereby selecting a no-target location because it was in that general area, rather than because its memory trace interfered with memory for the target).

However, one remaining problematic methodological aspect makes it difficult to conclude from this study that nonverbal irrelevant material leave traces in memory in the same manner as verbal material. Cornoldi and Mammarella (2006) used a straightforward 4 x 4 matrix. Such a matrix makes it very easy to use verbal coding to solve the task. Cornoldi and Mammarella did introduce a secondary task, but this was a tapping task designed to put further cognitive constrains on the participant, rather than an auditory disruption task that may have specifically limited verbal coding. Without a "pure" task tapping exclusively nonverbal memory, it is difficult to make claims on the basis of this study about the nature of nonverbal directed forgetting.

Palladino, Mammarella and Vecchi (2003) compared accuracy scores in a verbal versus nonverbal directed forgetting task. In the verbal condition, participants studied word lists, while in the spatial condition they were exposed to 5 x 5 matrixes, in which the TBR and TBF sets were highlighted by different colour markers. Subsequently, they were given a colour cue to indicate which items were to-be-remembered, followed by a recall task in which they were required to retrieve the TBR material. Palladino et al. manipulated the point at which the "forget" command was given - this was either during the encoding (IC) or the maintenance (IM) phase. They also included a baseline condition in which the "forget" cue was omitted, and varied the set size between 4, 6, and 8 items per TBF and TBR set. The stimuli were presented for 10 seconds followed by a 10 seconds maintenance period.

Palladino et al. found that in both verbal and nonverbal tasks, increases in set size led to performance deterioration. Giving the "forget" command during the maintenance phase made the task harder than in the IC or baseline condition, and this was true for both groups. In accordance with this, intrusion errors (i.e., incorrectly identifying a TBF item as to-be-remembered) were more likely to occur if the "forget" command was given during the maintenance phase. This is comparable to traditional directed forgetting research showing that TBF material sustains longer if the "forget" cue is delayed until the encoding process has been completed (see above). Presumably, in the IC condition (where the forget cue is given during encoding), TBF material was not encoded sufficiently to allow the emergence of intrusion errors. Of course, an additional interpretation not considered by the authors may have been that whenever participants received the cue to forget during encoding, they then proceeded to selectively concentrate on the TBR only, whilst not paying any attention to the TBF material at all.

There were also some performance differences between the verbal and nonverbal conditions: Performance was better in the IC condition than in the baseline condition, but this was true for the spatial version of the task only. Furthermore, set size only had an impact on the amount of intrusion errors in the spatial condition. Comparable numbers of intrusions were observed regardless of set size within the verbal group. In Experiment 2, participants were also required to retain the order in which verbal and spatial information had been presented. Here, intrusions were negatively related to an increase in set size in the spatial task, while the opposite pattern emerged in the verbal task.

Based on these results, Palladino et al. conclude that some functional difference must exist between verbal and nonverbal memory (although they do not speculate on what these differences might be). Some methodological limitations make it difficult to develop firm conclusions from this study: Firstly, while the verbal task involved free recall of the TBR words, the spatial task entailed a forced-choice recognition test requiring participants to select the TBR locations from a fixed set.

Thus, the two tasks were not comparable with respect to the mental processes they involved. Statistical power was compromised since the task involved six trials per condition with only 20 participants in total. This also must have impacted on accuracy – one error can substantially reduce percentages if the overall number of trials is low. Exposure to the test items was kept constant regardless of the set size – this may have had positive effects on learning the smaller sets, but a detrimental effect on participants' ability to retain the larger sets. Furthermore, in the spatial task , varying the set size while keeping constant the overall number of locations in the matrix meant that the probability of committing an intrusion error was not consistent across set sizes. As such, it is hard to draw meaningful conclusions from the data.

In summary, neither study convincingly shed light on the underlying mechanisms of nonverbal directed forgetting. Palladino et al.'s (2003) interpretation of their data is hampered by various methodological flaws. Cornoldi and Mammarella (2006) found some evidence that no longer relevant nonverbal material can leave traces in memory, but it is not clear whether participants' processing of their task was entirely free from verbal encoding.

Indeed, in an experiment that I conducted as a pilot to this thesis (Burghardt, 2003), I was not able to find any evidence of an intrusion cost with nonverbal material. To make the two tasks as comparable as possible, the study involved a replication of Oberauer's verbal modified Sternberg task (Oberauer, 2001), and a comparison of the results with a nonverbal variant. Participants studied either two lists containing four words (presented in two separate frames), or two frames each containing four locations marked by black dots. After a short delay, the words/locations disappeared from the screen, and one frame was covered by a red mask, indicating that participants should forget the items they had previously seen in this frame, and only continue to rehearse items from the opposite frame. At test, a single word/location was presented in a frame in the centre of the screen. Participants indicated whether they judged this probe to be from the TBR set by pressing "y". If they thought the probe had not previously been among the TBR set (i.e. either TBF or a new control probe that had been in neither set), they rejected it by pressing "n".

It is important to note at this point that, comparable to Oberauer (2001), and in contrast to both Palladino et al. (2003) and Cornoldi and Mammarella (2006), this study used a recognition task, rather than recall, and focused primarily on an analysis of response times. Using accuracy as a measurement of performance places the additional constraint on the task that it must stretch participants to a point where they are more likely to commit errors. A recognition task of the sort used here is unlikely to meet this criterion. Furthermore, response times are generally thought to provide a more sensitive measure of intrusions (Zacks et al., 1996). Thus, in line with Oberauer's methodology, evidence for the prevalence of no longer relevant memory traces was primarily assessed by means of an intrusion cost analysis (a comparison of response patterns to control and TBF probes).

Comparable to Oberauer (2001), the verbal condition elicited a reliable intrusion cost with median response times that were faster in response to control probes than TBF probes. In the nonverbal condition, there was some evidence suggesting that TBF probes were still present in memory: Accuracy was better when participants rejected control probes than TBF probes. However, no intrusion cost was found in the nonverbal condition – participants rejected TBF probes with the same speed as control probes. Furthermore, performance was poorest and slowest in response to TBR probes in the nonverbal condition, but not in the verbal condition.

Superficially, these results lent some support for the notion that verbal and nonverbal memory are segregated entities: An intrusion cost occurred with verbal but not with spatial locations. This could be interpreted as evidence that no longer relevant verbal material leaves a trace in memory for some time, allowing an intrusion cost to occur, while the same could not be argued about nonverbal material. However, it is not clear whether this is due to strict modality processing difference between verbal and nonverbal memory, or an additional factor not previously considered. Returning to a point raised earlier, the nonverbal condition contained stimuli that participants had not encountered before (locations within an otherwise blank frame), and therefore, they should not possess any existing traces of such items in their long-term memory. In contrast, the verbal task entailed common words that participants use frequently. Perhaps it was this difference that was responsible for the failure to detect an intrusion cost in the nonverbal task.

As suggested before, in explaining the occurrence of the intrusion cost, Oberauer placed great emphasis on the existence of stable traces in long-term memory that will decay only gradually even if attention is moved away from them. Arguably, if there is no matching representation for the TBF stimulus in memory, it would only leave a fragile trace that is particularly susceptible to fast decay once its rehearsal is aborted. Perhaps the reason why there was no intrusion cost with such spatial material was because what was left of the TBF memory traces when the probe was presented was not sufficient to trigger a familiarity signal.[2] As a consequence, participants processed TBF probes in the same way as control probes, leading to a quick rejection response on both counts.

[2] If indeed familiarity is triggered by successful matching of the stimulus and its corresponding representation in long-term memory – an assumption that will queried in Series 2 of this thesis.

The absence of pre-existing long-term memory traces could also explain why participants found it harder to reject a probe than accepting it as to-be-remembered. Without such traces aiding their performance, participants may have found it hard to maintain the nonverbal information in memory. The long response times to TBR probes add to this picture, indicating that participants did not rely on efficient familiarity signals but were forced to resort to more elaborate recollection processes reinstating the context in which the probe had been seen earlier.

To explore this issue further, the first part of my thesis was designed to investigate whether an intrusion cost can only emerge with nonverbal material when the no longer relevant material benefits from long-term memory representations, leading to a slower activation decay of the corresponding memory traces in comparison to stimuli that are not represented in long-term memory. Should this be the case, it would provide some evidence to suggest that the processes involved in the deliberate attempt to remove nonverbal information from memory are somewhat similar to verbal memory provided that nonverbal and verbal stimuli are matched with regard to long-term memory backup. Furthermore, if the intrusion cost only emerged in a condition containing items for which participants held pre-existing long-term memory representations, then this would offer support for the notion that long-term memory can have a direct impact on performance in working memory tasks. It would also be in line with Oberauer's adaptation of Yonelinas' interpretation of recognition memory (Yonelinas, 1999), whereby the familiarity signal underlying the intrusion cost is based on the successful detection of a long-term memory representation that matches the TBF stimulus.

(2) SERIES 1: THE INTRUSION COST & LONG-TERM MEMORY

The first part of this thesis explored whether long-term memory can influence the activation decay of a memory trace for spatial information. All of the experiments in this section rest on the assumption that familiarity is caused by resilient long-term memory representations matching the incoming stimulus (an assumption that will be scrutinised at a later stage in Series 2).

Experiments 1A-1C entailed the systematic manipulation of the extent to which participants had stable long-term memory representations of the test items in a nonverbal modified Sternberg task. In each trial of the task, participants memorised two sets of locations presented in a frame on the computer screen. One location set was then declared as no longer relevant. At test, a single location was presented, requiring participants to identify whether this was one of the locations that they had to remember. The task used stimuli that participants were relatively unfamiliar with (quasi-random locations on the computer screen). Two kinds of prior training strategies were used: In Experiment 1A, test items were selected from the same fixed set of principal locations, thereby gradually familiarising participants with the stimuli used throughout the experiment. In order to assess whether this repeated use of the same principal locations would leave an implicit memory trace stable enough to trigger an intrusion cost, performance was compared between the first and last 30 trials of the study. In Experiments 1B and 1C, this strategy was replaced by an explicit training approach: Prior to their participation in the modified Sternberg task, participants learned the position of the locations that would be used in the study. Their performance was compared with that of a control group that did not partake in the training session.

The exploration of the creation of long-term memory representations through both implicit and explicit means seems justified because the recent literature has established that the formation of memory traces varies depending on whether it is carried out implicitly or explicitly. The following section briefly summarises some of the main findings suggesting that implicit and explicit memory are segregated processes.

(2.1) Experiment 1A

(a) Implicit versus Explicit Memory

While explicit memory is defined as a conscious retrieval process, implicit memory is thought to reflect the ability to access information stored in memory without conscious awareness (Chun and Jiang, 2003). Neuropsychological studies show that explicit memory is supported by limbic and diencephalic parts of the brain, whereas implicit memory relies on the basal ganglia and candate nucleus (see Gronin-Colomb, Gabrieli & Keane, 1996). Only the right hemisphere of the brain appears to be engaged in explicit memory, while both right and left hemisphere support processes involved in implicit memory (Gronin-Colomb, et al. 1996). Fleischman, Vaidya, Lange and Gabrieli (1997) reported intact explicit and impaired implicit memory in a patient who had most of his right occipital lobe removed during brain surgery. Memory deficits in amnesia are only found in explicit, but not in implicit memory tasks, suggesting that amnesic patients are unaware of what they have stored in memory (Roediger, 1990). Implicit memory impairment is found in patients with nonhippocampal brain damage, but these patients do not suffer from deficits in explicit memory (see Chun and Jiang, 2003), suggesting that implicit memory cannot merely be understood as a robust form of explicit memory.

Because implicit memory does not rely on conscious search processes, it is thought to be better equipped for storing more complex knowledge structures. Seger (1994) argues that perceptual-motor learning (e.g. how to ride a bike) and unstructured learning require the use of implicit memory, while explicit memory is engaged in structured learning through verbal interactions. Implicit learning can create long-lasting and robust memory representations (Chun and Jiang, 2003). Although implicit memory is thought to be incidental, some attention to the to-be-encoded stimulus is required, and it is therefore not an entirely automatic process (Seger, 1994).

Research suggests that the implicit formation of memory traces is not something that is confined to verbal memory. For example, Chun and Jiang (e.g. 2003) demonstrated that it is possible to create long-term memory representations of spatial configurations in the absence of explicit awareness. Using a contextual cuing task, participants were required to identify the direction of a target "T" within a configuration of 11 "L" distractors. Unbeknownst to the participants, some of the configurations were repeated several times throughout the experiment. Chun and Jiang found that participants' response latencies to repeated configurations were shorter than to new configurations, suggesting that they had created some form of memory of configurations that were represented repeatedly throughout the experiment. They demonstrated that this memory was not explicit: given a repeated spatial context, participants were unable to predict where the target would appear. Chun and Jiang found a long-lasting effect of this implicit memory: The response latency advantage gained through the implicit learning of repeated configurations was robust enough to survive for as long as one week, when participants were tested again (Experiment 3). They suggested that the effects of contextual cuing develop rapidly and can already be observed after only five or six configuration repetitions. Research by Howard and colleagues (Howard, Howard, Dennis, Yankovich & Vaidya, 2004) found corroborating evidence and in addition suggested that implicit contextual cuing remains intact across different age groups. In a recent study, Jiang et al. (2005) demonstrated a high capacity in learning visual configurations: In their study, participants showed priming effects to up to 60 different configurations that were still observable after one week.

That it is possible to create long-term memory representations of spatial locations has also been demonstrated in a sequential spatial memory study by Kemps (2001). Kemps argued that in memory of location sequences, path patterns that are predictable due to perceptual redundancy elicit higher recall because pre-existing long-term memory representations for redundancy laws (symmetry, repetition and continuation) may contribute to performance. She assessed this idea by training participants on complex path sequences prior to testing (following a procedure developed by Hebb (1961) whereby training is accomplished through repeated exposure to the complex sequences) and found that this improved performance substantially, and, importantly, that it did not translate to untrained complex path sequences (suggesting that improved performance was not simply due to practice effects).

These findings indicate that the mere repeated exposure to spatial stimuli can be sufficient to create an implicit and relatively robust long-term memory of spatial configurations. Therefore, in Experiment 1A, test items were continuously selected from a small set of fixed locations (location set A) over the course of 150 trials. Performance in this "learning" condition was compared between the first and last 30 trials. In addition, a control condition was included where a different group of participants were exposed to 30 trials using items from location set A, followed by 90 trials with items from a different location set (location set B), before returning to location set A for the final 30 trials of the experiment (see Figure 2, p. 56). Within each trial, participants studied the location of three blue and three orange locations presented in the form of dots within a framed area in the centre of the computer screen. Subsequently, the frame and its content disappeared, and the colour of the screen changed into either blue or orange, thereby indicating whether participants had to remember the blue or orange dots. After a short delay, one frame reappeared with one location highlighted in black. Participants needed to judge whether this location had been integrated in the TBR configuration.

The focus of this study was on a response times comparison between control and TBF probes in the first and last 30 trials of each condition. This was done to explore the hypothesis that no longer relevant traces can only remain activated in memory (and thus trigger a familiarity signal once a TBF stimulus is represented) if they form a stable part of long-term memory. If the implicit formation of memory traces of the stimuli is sufficient to create an intrusion cost (longer response times to reject TBF probes relative to control probes), then such effect should only be observed in the last 30 trials of the learning condition. In the control condition, the practice of a location set different from the one analysed should prevent the formation of implicit memory traces of the test items, and consequently, any intrusion cost.

<u>(b) Method</u>

(i) Participants

51 undergraduate students of the University of Plymouth participated in this study, some in exchange for course credit, and others in exchange for small

payment. 5 participants were dropped from the data pool, because their accuracy performance failed to exceed chance, leaving a total of 23 participants in each condition.

(ii) Materials

The data was collected using a computer program written in e-prime (www.pstnet.com/eprime). The experiment was carried out on a 17"monitor set to a resolution of 1024*768 pixels. Two location sets A and B were created, spreading across the entire screen and each containing 9 fixed locations (see Figure 2, p. 56). The locations were represented by dots (1.4 cm in diameter), and they were allocated in contradiction with Gestalt laws (i.e. no two locations were on the same horizontal or vertical level). This was done because such arbitrary perceptual relationship between locations makes it more difficult for participants to resort to verbal encoding (e.g. "second location from the top", "third on the left"). In each trial, a combination of six locations was selected; three of those were highlighted as orange dots, the other three were highlighted as blue dots, and the rest remained invisible. While the combination of locations within each trial was fixed, steps were taken to guarantee that no location combination was used more often than three times, and that no location combination would be used again after less than 30 trials. Apart from this constraint, the order of the trials was randomised across participants. The probe appeared as a black dot, while all other locations were held invisible.

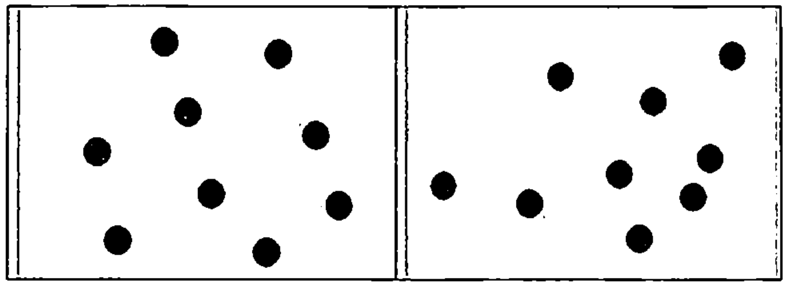

Figure 2: Location sets A (left) and B (right) used in Experiment 1A. Participants in the learning condition worked with location set A only. Those assigned to the control condition studied stimuli selected from location set A in the first and last 30 trials of the experiment, and location set B in between. In each trial, two stimuli sets containing three locations each were presented to participatns in red and blue colour markers; the remaining locations remained invisible.

(iii) Procedure

This experiment included a 2 (implicit learning versus control condition) x 3 (probe type: TBR, TBF, or control probe) x 2 (critical trials: first or last 30 trials) mixed design. Half of participants were assigned to the learning condition, the other half participated in the control condition.

The procedure was identical for both control and learning condition (see Figure 4, p. 58), with the exception of the location sets used across the tasks. In the learning condition, locations were selected from the same location set A throughout the 150 trials of the experiment. In the control condition, location set A was used only in the first and last 30 trials. In between those trials, test items were selected from a second location set B (see Figure 3, p. 57). Sets A and B did not share any locations.

	Trials 1-30	Trials 31-120	Trials 121-150
Learning condition	A	A	A (✓)
Control condition	A	B	A

Figure 3: Design of Experiment 1A. In the learning condition, to-be-learned location sets were always selected from the same fixed set of locations (location set A). In the control condition, stimuli were from location set A only in the first and last 30 trials. In between, participants studied locations from a second location set B. Trials that were analysed are highlighted in **bold**. (✓) indicates where an intrusion cost was predicted.

In each trial, participants studied the location of the three orange and three blue dots presented in a single frame for 7800 ms (1300 ms x the number of items on the screen) on the screen. Subsequent to a further 800 ms grey visual mask, the entire screen then changed colour to either blue or orange, thereby indicating the locations that participants had to remember (2000 ms). Immediately afterwards, the frame reappeard containing a single location presented in black colour. Participants were instructed to press "y" on their keyboard if they thought this probe matched one of the TBR locations. Otherwise, they pressed "n" to reject this probe as not to-be-remembered. The probe display remained on the screen until a response was recorded. Feedback about accuracy and speed was presented on the screen for 1500 ms after each trial. The next trial commenced after 1000 ms. Participants were familiarised with these procedures in four practice trials (two for each location set A and B, regardless of the condition that the participant was assigned to) prior to the actual test trials.

TBR and TBF sets were both presented equally often in orange and blue dots. The location combinations were fixed in each trial, but the order of trials was randomised to ensure that participants were unable to predict the colour of the upcoming TBR items (see above). In the first and last 30 trials, and in between those crucial trials, all three probe types (TBR, TBF and control probe) were presented with the same frequency, and in randomised order.

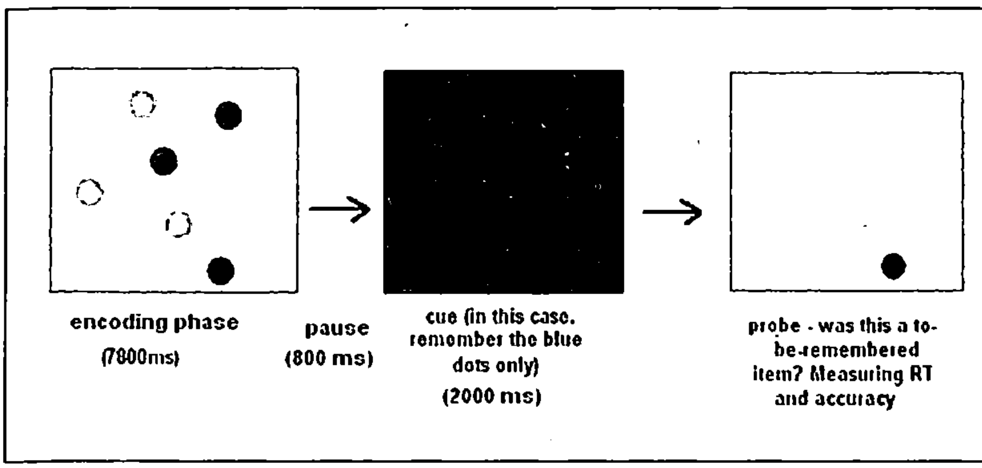

Figure 4: Basic procedure in Experiment 1A. Participants memorised the locations of three blue and three orange dots on the screen (here presented in grey and black). Subsequently, a colour mask indicated which locations were to-be-remembered. At test, participants judged whether a single location (presented in black) was a TBR item or not.

(c) Results

Response latencies and accuracy were analysed using a 2 (critical trials: 30 first and last trials) x 3 (probe type: TBR, TBF and control probe) x 2 (condition: learning versus control condition) mixed ANOVA (condition was the between-subjects factor). For median response times analyses, only correct responses were used (this is also true for the remaining studies in this thesis). Where Mauchly sphericity checks were significant, degrees of freedom were adjusted accordingly.

Results were analysed with two objectives in mind: First of all, it was examined whether the implicit learning manipulation had successfully changed participants' response pattern in comparison to the control condition. Secondly, to establish whether an intrusion cost had occurred, responses to TBF and control probes were compared separately. Only the main results relevant to these two objectives are mentioned here. For further results, please consult the appendices section.

(i) Implicit Learning Effects on Response Times

Results showed a significant main effect for critical trials ($F_{1, 44}$ = 40.8, *MSe* = 60633.8, $p < 0.001$), indicating that performance had accelerated significantly in the last 30 trials (*M* = 817.3 ms, *SD* = 260.4) in comparison to 1006.7 ms (*SD* = 297.0) in the first 30 trials). However, despite the repeated use of the same locations in the learning condition only, response times were comparable between the control and learning conditions. No significant main effects of condition ($F_{1, 44}$ = 0.1, *MSe* = 369320.6, p = 0.7), and or interaction were found between probe type and condition ($F_{1.6, 68.9}$ = 1.0, *MSe* = 17348.5, p = 0.35). The three-way interaction between probe type, time of testing, and condition was not significant ($F_{1.7, 75.9}$ = 1.6, *MSe* = 9508.9, p = 0.2). Figure 5 (p. 60) confirms that performance patterns were comparable between the two conditions.

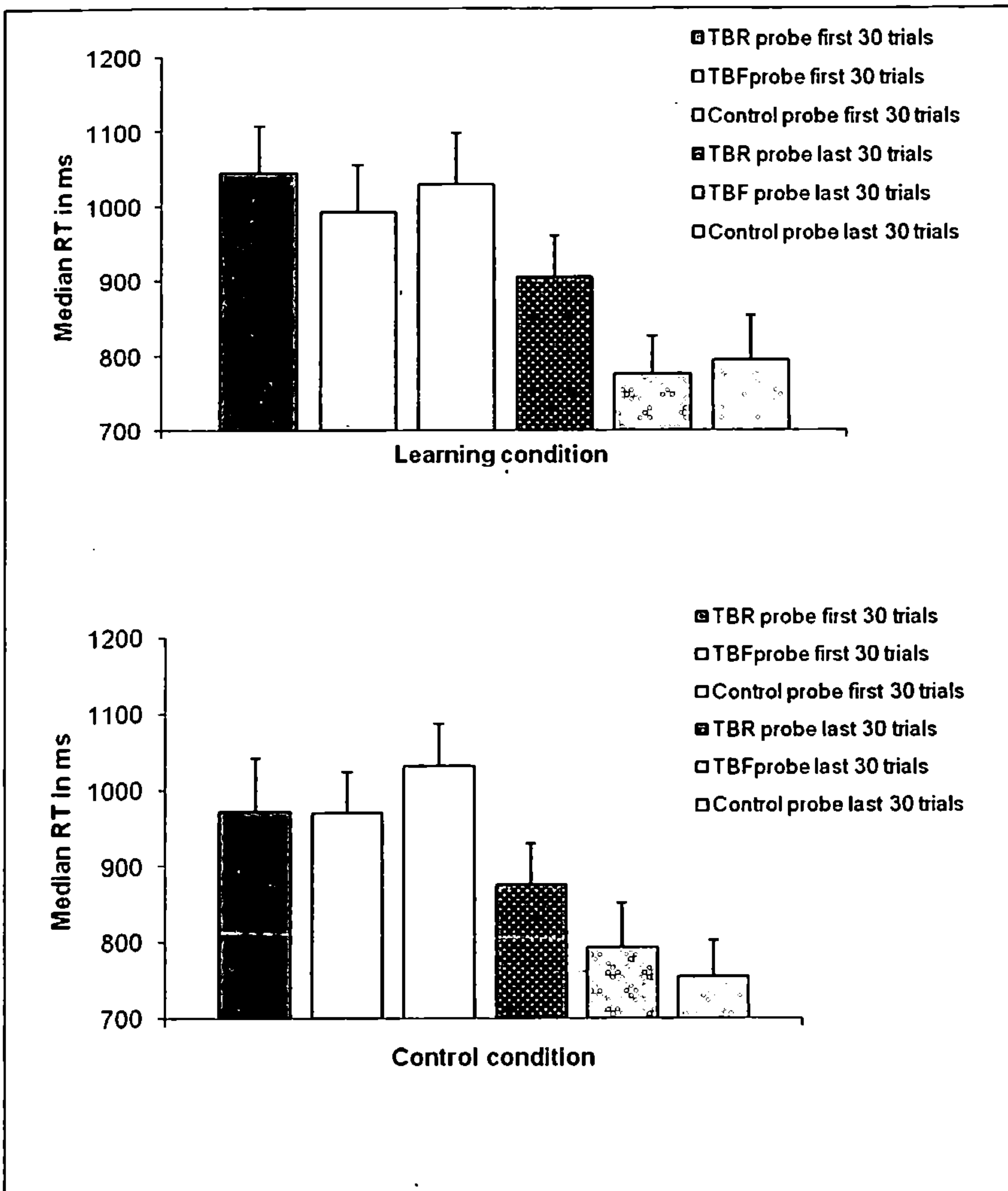

Figure 5: Median response times in Experiment 1A. Error bars represent one standard error of the mean. A comparison of response times to TBF and control probes shows clearly that there was no apparent intrusion cost in control and implicit learning condition – with the exception of the last 30 trials in the control condition, response times were typically faster in response to TBF than control probes. In both conditions, performance accelerated in the last 30 trials in comparison to the first 30 trials.

(ii) Intrusion Costs in Response Times

In spite of the lack of significant interactions (see above), a priori hypotheses demanded a more fine-tuned post hoc analysis to assess the presence of an intrusion cost. Findings summarised in Table 1 (p. 61) indicated that no intrusion cost occurred anywhere throughout the experiment. The only observable response latency differences between control and TBF probes were found in the first 30 trials of the control condition – and this effect pointed in the opposite direction of the intrusion cost, because participants rejected TBF probes faster than control probes.

	First 30 trials	**Last 30 trials**
Learning Condition	$p = 0.131$ (probe main effect: $F_{2, 44} = 1.8$, $MSe = 8853.3$, $p = 0.173$)	$p = 0.323$ (probe main effect: $F_{2, 44} = 18.8$, $MSe = 6030.0$, $p < 0.001$)
Control Condition	$p = 0.017$ TBF probes: $M = 969.5$ ms, $SD = 260.9$ Control probes: $M = 1031.0$ ms , $SD = 269.9$ (probe main effect: $F_{1.4, 30.6} = 1.5$, $MSe = 17534.3$, $p = 0.244$)	$p = 0.103$ (probe main effect: $F_{2, 44} = 9.4$, $MSe = 9571.4$, $p < 0.001$)

Table 1: Intrusion cost analyses (LSD pairwise comparisons of TBF and control probes) in the response times data of Experiment 1A.

(iii) Implicit Learning Effects on Accuracy

Accuracy analyses revealed a general pattern of results that was comparable results to that reported above (see Figure 6, p. 63). Participants in both conditions exhibited clear signs of practice, as indicated by the overall improved performance in the last 30 trials (M = 88.2%, SD = 15.4) in comparison to the first 30 trials (M = 80.9%, SD = 14.9; $F_{1, 44}$ = 33.6, Mse = 108.1, $p < 0.001$). There was also a significant interaction between probe type and critical trials ($F_{1.7, 74.7}$ = 13.6, MSe = 161.6, $p <$ 0.001). T-tests suggested that this result was mainly due to a more accurate rejection of control probes (M (first 30 trials) = 78.2%, SD = 17.2; M (last 30 trials) = 94.8%, SD = 9.1; t (45) = 6.5, p < 0.001) and TBF probes (M (first 30 trials) = 88.4%, SD = 11.2, M (last 30 trials) = 94,9%, SD = 8.5; t (45) = 3.5, p = 0.001) in the last 30 trials. Performance remained stable in response to TBR probes (M (first 30 trials) = 76.1%, SD = 13.0, M (last 30 trials) = 74.8%, SD = 17.2; t (45) = 0.5, p = 0.598).

The implicit learning manipulation, on the other hand, did not appear to have an additional effect on participants' performance. There was no main effect for condition ($F_{1, 44}$ = 2.3, Mse = 285.9, p = 0.140). Neither probe type ($F_{1.6, 71.6}$ = 0.5, MSe = 228.0, p = 0.584) nor critical trials ($F_{1, 44}$ = 2.5, Mse = 108.1, p = 0.118) interacted with condition, and there was also no significant three-way interaction between the three variables ($F_{1.7, 74.7}$ = 0.2, Mse = 161.6, p = 0.804).

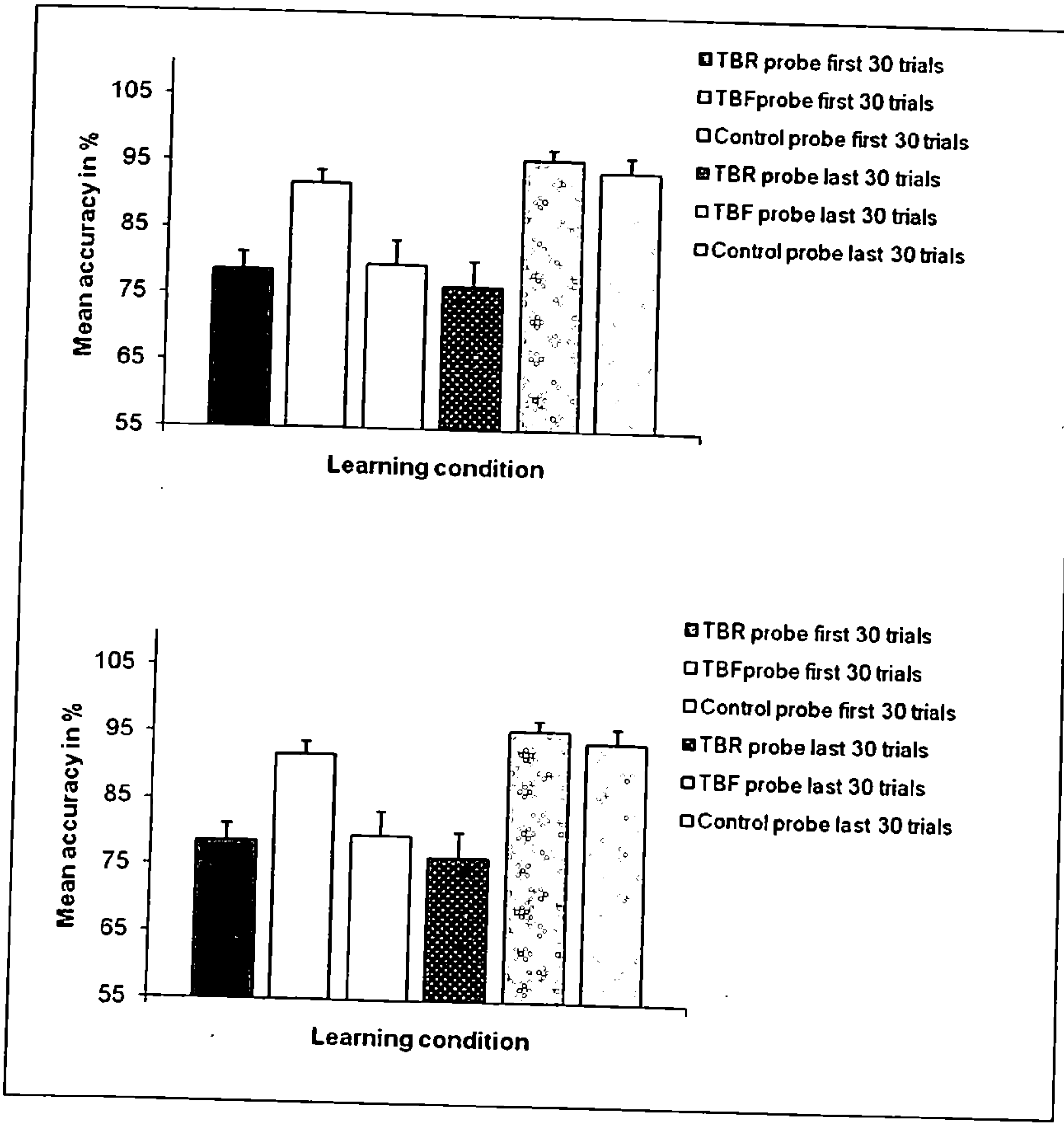

Figure 6: Mean accuracy in Experiment 1A. Error bars represent one error of the mean. The graphs demonstrate no apparent intrusion errors in any of the two conditions – accuracy was typically better in response to TBF than control probes. In both conditions, performance was better in the last 30 trials of the experiment – but this was only the case for negative (TBF and control) probes.

(iv) Intrusion Errors in Accuracy

Due to a priori predictions a post hoc analysis was carried out to measure any observable intrusion errors, in spite of an absence of significant interactions. Table 2 (p. 64) shows that there was no evidence to suggest that participants were significantly more accurate when rejecting a control probe relative to a TBF probe. Where significant performance differences were found, they were in the opposite direction to those associated with intrusions.

	Learning condition		Control condition	
	M	SD	M	SD
TBF probes	91.7%	9.8	85.0%	11.7
Control probes	79.9%	17.3	76.5%	17.2
Difference between TBF and Control probes	$p = 0.005$		$p = 0.011$	
Probe main effect	$F_{1.4, 30.8} = 6.7$, $MSE = 256.8$, $p = 0.008$		$F_{1.2, 27.0} = 32.5$, $MSE = 184.5$, $p = 0.032$	

Table 2: Accuracy comparisons (LSD pairwise comparisons) between TBF and Control probes to assess the occurrence of intrusions in the first 30 trials. In the last 30 trials, there were no significant differences between TBF and Control probes in either condition (p = 0.502 (probe main effect: $F_{1.2, 27.0} = 32.5$, $MSe = 184.5$, $p < 0.001$)and 0.492 (probe main effect: $F_{1.4, 32.7} = 15.3$, $MSe = 225.8$, $p < 0.001$) for control and learning condition, respectively).

(d) Discussion

The results reported above illustrate that mere re-exposure to the same locations over time is not sufficient to trigger any changes in participants' response patterns in the spatial modified Sternberg task. There was no evidence that the use of the same locations had a beneficial effect on performance – participants performed comparably in terms of accuracy and response times regardless of the condition they had been assigned to.

Overall, there was no evidence of an intrusion cost or intrusion errors in the control condition. Importantly, the repeated use of the same locations throughout the experiment also failed to trigger an intrusion cost in the learning condition. This is in conflict both with a priori predictions, and also with findings by Cornoldi and Mammarella (2006) who detected intrusion errors in the accuracy data of their nonverbal directed forgetting study. The present results support the argument that perhaps, the underlying cause of the intrusion errors in Cornoldi and Mammarella (2006) may be found participants' verbal encoding strategies.

The only observable change appeared to be an overall improvement in performance (presumably due to practice effects) applicable to both learning and control conditions. Interestingly, this improvement was apparent only in the two negative probes (TBF and control probes), but not the TBR probe, suggesting that over time, participants became better at correctly rejecting probes as not to-be-remembered, but not at identifying a TBR item. This indicated that it is difficult to successfully retain and rehearse an item that is not firmly represented in long-term memory). One alternative interpretation of the increasing accuracy in response to negative probes was that perhaps, due to the difficulty of the task, participants developed an inclination to declare all probes as novel. However, it is unlikely that this is a convincing explanation. If participants had developed a tendency to reject all probes, performance should have been particularly poor with TBR probes. Instead, there was no main effect for probe type in the learning condition, and even in the control condition, performance in response to TBR items did not drop below 73%, making it unlikely that participants indiscriminately rejected all probes.

In hindsight, it is plausible to argue that perhaps the implicit learning strategy was not stringent enough to allow the formation of memory traces of the locations in long-term memory. In previous implicit spatial memory studies, participants were exposed to the complete configurations on which they were re-tested over time (e.g. Chun & Jiang, 2003). In the present study, however, the nine fixed locations were never presented simultaneously at any point. Because participants merely saw incomplete parts of the principal configuration from which the test items were drawn, it is possible that they did not develop a stable representation of the locations in long-term memory. The experiment did not include a direct measure of participants' memory of the test items, and it is therefore difficult to assess the extent to which the creation of long-term memory representations was successful.

In order to address the methodological issues identified in this study, several changes were introduced in the design of in Experiments 1B and 1C. Rather than using an implicit training strategy to create memory representations for the locations, the following experiment employed an explicit training approach. Participants in the practice condition learned the principal locations used throughout the experiment prior to the critical task. Subsequent to the testing session, participants' memory was assessed once again to verify whether they had retained the test locations throughout the entire experiment. Those assigned to the control condition participated in the study without any pre-test training.

The repeated use of the same set of locations throughout the study raises the potential concern that over time, as each location is presented repeatedly, each of them may eventually become equally activated in memory, and thus equally familiar to the participant. In addition, there is the possibility that in the following study, the explicit pre-test training of the test items might create stable memory representations of the stimuli which may thwart an activation (and - by association - familiarity) decay of locations that had been encountered in a previous trial (e.g. a control probe location could still trigger a familiarity signal and be regarded as "old" due to its appearance in previous trials). This may reduce the utility of familiarity as a basis for a response, thereby creating indistinguishable reaction time and accuracy scores in response to the three probe types. However, as results from the learning condition in the previous study demonstrate, this does not appear to occur. Despite the use of the same principal location set, there were clear response latency and accuracy differences between the three probe types even in the last 30 trials of the experiment. I therefore did not predict that the training session and repeated use of the same principal locations combined would create a situation where inter-probe accuracy and response times discrepancies would disappear.

(2.2) Experiment 1B

Experiment 1A suggested that the implicit formation of representations corresponding to the test items may perhaps not be sufficient to elicit an intrusion cost for no longer relevant spatial locations. In Experiment 1B, the gradual implicit formation of long-term memory representations was replaced by an explicit training session. One group of participants was assigned to the learning condition in which, prior to testing, they memorised the principal locations from which the test items were selected in the modified Sternberg task. In order to make it easier for participants to learn these exact locations, they were presented in a grid containing 32 squares (see Figure 7, p. 69). Only 12 of these were used throughout the study. In the training session, participants studied the grid with these crucial 12 locations highlighted in black and then replicated the 12 locations on an empty paper grid until they were able to do so accurately on at least two successive occasions. Afterwards, they proceeded to participate in the main memory task. Participants in the control condition did not participate in this pre-test training session. In order to ascertain that those in the learning condition had retained the crucial locations throughout the experiment, their memory of the test locations was tested again at the end of the session.

Similar to Experiment 1A, the aim of this study was to assess whether explicitly learning the test stimuli would increase the likelihood of observing an intrusion cost. To do so, the primary focus was again on a comparison of response times to TBF and control probes. If the training session enables the formation of sustainable traces in memory, and if the intrusion cost is due to residual long-term memory representations slowing down the decay of TBF information in memory, then only the learning condition should yield a significant intrusion cost.

(a) Method

(i) Participants

51 undergraduate students from the University of Plymouth participated in this study in exchange for course credit or small payment. All participants reported that they were not colour blind and had normal or corrected to normal eyesight. 25 participated in the control condition, 26 in the learning condition. In the latter, one participant failed to correctly remember all 12 locations in the post-test recall task, and was therefore excluded from the analysis.

(ii) Materials

As in experiment 1, data was collected using a computer program set up with e-prime (www.pstnet.com/eprime). The experiment was displayed on a 17"monitor (set to a resolution of 1024*768 pixels). A grid containing 32 locations was generated. No two locations shared the same x or y coordinates to avoid identical horizontal and vertical levels, thereby making verbal encoding harder. Each location was marked by a 0.8 x 1.0 cm square. Only 12 of these locations were used in the experiment. For the purposes of the training session and the post-test recall task, replicas of the grid were created on paper for participants to fill in (see below for a more detailed description of the training session).

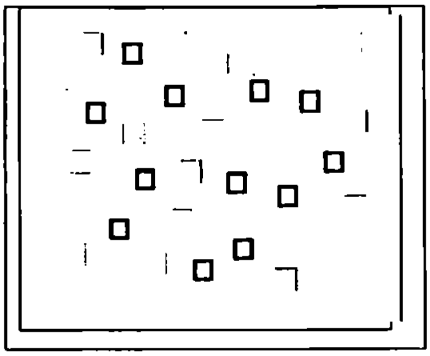

Figure 7: Grid used in Experiment 1B and 1C for training purposes. Locations used in the memory task were selected from the black squares only.

(iii) Procedure

A 2 (learning versus control condition) x 3 (probe type: TBR, TBF, and control probes) mixed design was used. Half of participants were assigned to the learning condition, the other half to the control condition.

Pre-test training session: Prior to testing, those assigned to the learning condition were trained to memorise the 12 locations used in this experiment. In addition, they also participated in a post-test recall (see below). In the training session, they studied an image outlining the 12 locations within the grid in their own time (cf. Figure 7, p. 69). They then received empty grids on paper and a pen. They were instructed to highlight the 12 locations in this grid from memory. Once participants were able to point out the 12 locations in the grid accurately at least twice in a row, they were allowed to proceed to the actual task.

Main memory task: The procedure of this task was identical to Experiment 1A (see Figure 8, p. 71) save for a few exceptions: Because the stimuli and probe were presented in a grid, rather than in an otherwise blank frame, this may have made the task too easy for the purposes of enticing any substantial accuracy or response times differences between the three probes. Therefore, the set size of the TBR and TBF groups was increased to four locations.

In each trial, the configuration grid with the 32 squares was presented in a 10.5 x 18.5 cm frame in the centre of the screen. In this grid, four squares were coloured in orange, four were coloured in blue, and the rest remained empty. The coloured squares were selected from a fixed subset of 12 locations (see Figure 7, p. 69). Location combinations were fixed within each trial, but care was taken to avoid excessive repetition of any configuration (i.e. no configuration appeared more than twice). Participants were instructed to study the locations of the coloured squares. After 10400 ms (1300 ms x 8 test items), the grid disappeared in exchange for a grey mask. After 800 ms, the screen then changed into either blue or orange for 1000 ms, indicating the colour of the squares that participants were instructed to remember. This was followed by a visual grey mask (300 ms). Immediately afterwards, the grid reappeared with one square coloured in black. Participants judged whether this square had been one of the previous TBR locations. They pressed "y" if they thought so, otherwise they pressed "n". The probe display remained on the screen until the participant had responded. Feedback indicating whether the response had been correct appeared in written form on the screen for 1500 ms. After a 1000 ms pause, the next trial was initiated. The order in which blue or orange squares were declared to-be-remembered was randomised. The order of the probe types (TBR, TBF, or control probe) was also randomised across trials. Every location was used at least once, but no more than twice, for every probe type. There were 45 trials (15 per probe type) in addition to 5 practice trials familiarising participants with the procedures of the experiment.

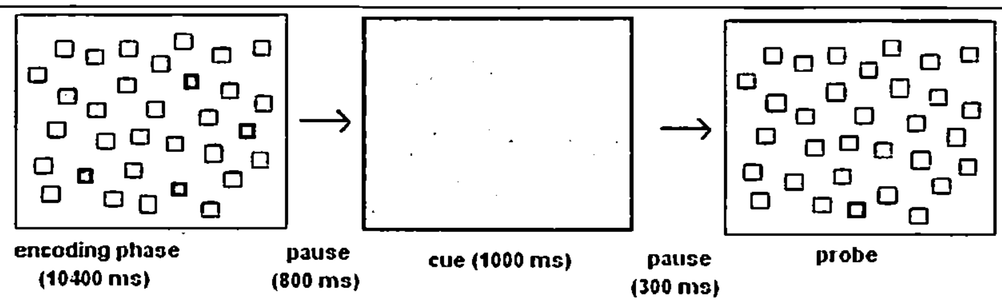

Figure 8: Basic design in Experiment 1B. In each trial, participants memorised two sets of locations presented in blue and orange (represented here in black and grey). Subsequently, a colour cue indicated those items that participants had to retain in memory. At test, participants judged whether the probed location had been part of the TBR configuration.

Post-test verification task: Subsequent to the main memory task, participants assigned to the learning condition received one more paper grid to fill in, in order to assess whether they had retained all 12 locations in memory.

(b) Results

Median response times and accuracy were analysed using a 2 (condition) x 3 (probe type) mixed ANOVA with condition as between-subjects factor. With the exception of one participant whose results were not included in the analysis, all participants in the learning condition successfully learned and remembered all 12 locations and were able to reproduce them correctly in a grid subsequent to the experiment. The primary focus of the analysis was again on an assessment of any changes induced by the training session, and a comparison of responses to TBF and control probes. Therefore, a priori predictions required that post hoc comparisons would be carried out regardless of the outcome of interaction analyses.

(i) Median Response Times Analysis

An analysis of median response times across conditions revealed no significant main effect of probe type ($F_{2, 96}$ = 0.2, *MSe* = 26621.3, p = 0.81). Figure 9 (p. 73) confirms that response latencies were similar within and between the two conditions.

Learning Effects. There was no significant main effect of prior learning of the set of locations ($F_{1, 48}$ = 0.9, *MSe* = 334715.1, p = 0.352), and the interaction between condition and probe type was also not significant ($F_{2, .96}$ = 0.4, *MSe* = 26621.3, p = 0.669). This indicated that participants performed similarly regardless of the condition they had been assigned to.

Intrusion Costs. The main effect for probe type was not significant in either condition ($F_{2, .48}$ = 0.6, *MSe* = 23788.1, p = 0.531 and $F_{2, .48}$ = 0.039, *MSe* = 29454.4, p = 0.962). There were no response times differences between TBF and control probes in control condition (p = 0.524) and learning condition (p = 0.934).

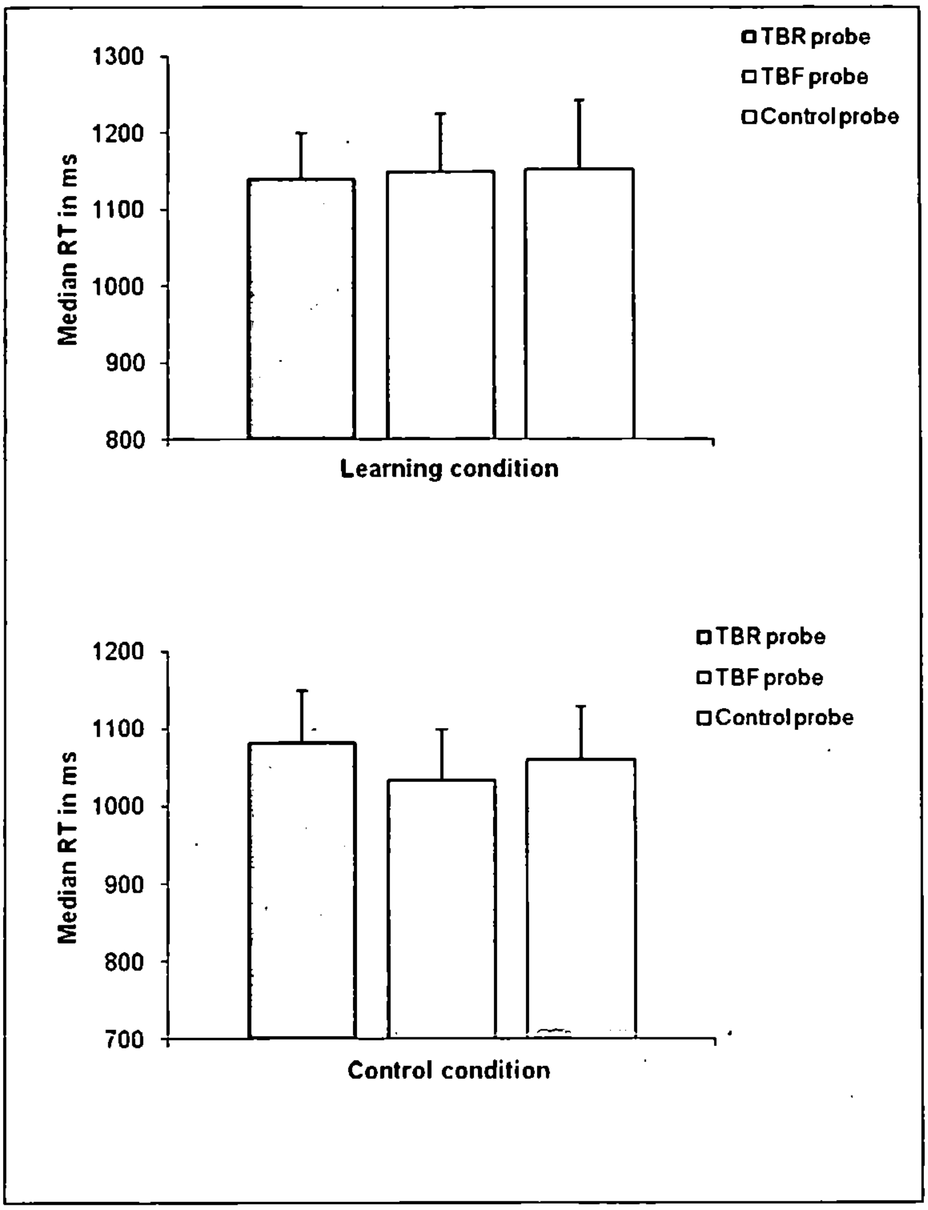

Figure 9: Median response times in Experiment 1B. Error bars represent 1 standard error of the mean. As can be seen in this graph, no intrusion costs emerged in either condition – response times were very similar for TBF and control probes. Response times were comparable between the two conditions, suggesting that the training session did not accelerate participants' performance.

(ii) Accuracy Analysis

There was a significant overall main effect of probe type ($F_{1.5, 73.6} = 6.6$, $MSe = 207.5$, $p = 0.005$). LSD tests suggested that across conditions, performance was significantly poorer in response to TBR probes ($M = 75.2\%$, $SD = 15.5$) than TBF probes ($M = 84.3\%$, $SD = 12.5$; $p < 0.001$). Performance was also slightly better in response to TBF than control probes ($M = 80.4\%$, $SD = 5.3$; $p = 0.083$).

Learning Effects. There was no significant main effect of condition ($F_{1.5, 73.6} = 0.7$, $MSe = 316.9$, $p = 0.403$), and the interaction between condition and probe type ($F_{1.5, 73.6} = 0.571$, $MSe = 207.5$, $p = 0.523$) was not significant either. This indicated that performance was comparable regardless of whether participants had memorised the test locations prior to the experiment.

Intrusion Errors. There were no significant differences between TBF and control probes in the control condition ($p = 0.626$; main effect for probe type $F_{1.4, 34.6} = 2.8$, $MSe = 182.8$, $p = 0.091$). Accuracy discrepancies between the two negative probes were marginally significant in the learning condition ($p = 0.076$, main effect for probe type $F_{1.6, 38.2} = 4.2$, $MSe = 234.0$, $p = 0.031$) – but this effect was in the opposite direction of an intrusion error (see Figure 10, p. 74).

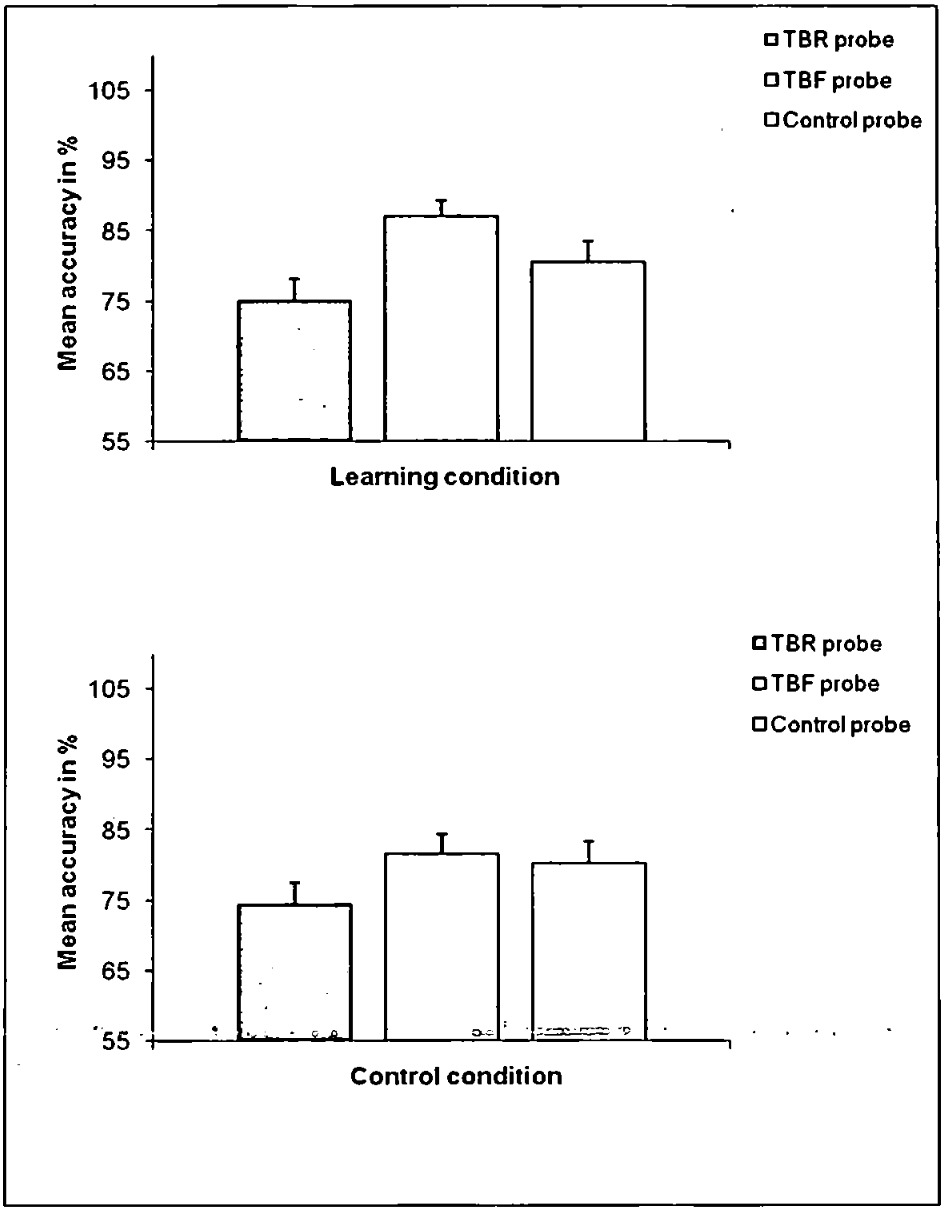

Figure 10: Mean accuracy (in %) in Experiment 1B. Error bars represent 1 standard error of the mean. Comparable to what was found with response times, there was no evidence of an intrusion error in the data. In the learning condition, the accuracy difference between TBF and control probes even pointed in the opposite direction of an intrusion error. Furthermore, performance appeared unaffected by the prior training session – participants performed comparable regardless of whether they had partaken in the learning or control condition.

(c) Discussion

Participants assigned to the learning condition successfully remembered all test locations even after the experiment, suggesting that the training session created long-term memory representations stable enough to sustain the entire experiment. In Experiment 1A, participants did not reject control probes faster than TBF probes. This was attributed to the possibility that an implicit learning manipulation may not be sufficient to form long-term memory representations that can trigger an intrusion cost. Here, the post-test verification task demonstrated that participants had retained the test stimuli in memory throughout the experiment. Despite this, there were again no observable intrusion costs in the learning or control condition. In addition, there was no significant main effect of condition, suggesting that performance remained unaffected by the explicit training manipulation. Experiment 1A and 1B therefore seem to indicate that whether or not a no longer relevant memory trace forms a part of long-term memory has little impact on the way in which it is ignored.

Such a finding may be problematic for Oberauer's interpretation of the intrusion cost (Oberauer, 2001). To recapitulate, Oberauer argued that TBF probes are rejected less quickly than control probes, because their corresponding memory trace is still residually activated in memory, thereby triggering a familiarity signal prompting participants to initially consider this probe as part of the TBR set. Overwriting this initial response in order to make a correct rejection response requires time-consuming recollection processes. In this model, the slow decay of traces that are no longer rehearsed is attributed to their stable representation in long-term memory preventing the immediate activation loss once attention is deployed elsewhere. Yet, there was no intrusion cost in Experiment 1B, regardless of whether or not participants had learned and retained the test stimuli in memory throughout the duration of the task. This is potentially at odds with an interpretation assigning the intrusion cost to an involvement of long-term memory.

Previous research has shown that when an item was already represented in long-term memory, performance in working memory tasks was enhanced (Hulme et al., 1991, Porier & Saint-Aubin, 1995). This was not the case in Experiment 1B: Accuracy was poorest in response to TBR probes, regardless of whether participants had learned the test stimuli prior to the main memory task. In the learning condition, participants were able to point out the test locations even after the experiment, thereby demonstrating that long-term memory traces corresponding to the test stimuli had survived throughout the course of the testing session. All the same, this did not appear to improve accuracy in response to TBR probes in comparison to the control condition. Such lack of effect is therefore in conflict with the notion that long-term memory can improve performance in working memory tasks.

Overall, such interpretations should be viewed with caution, since one methodological aspect of this experiment might have introduced noise to the data. Both TBR and TBF sets were presented within the same frame. This was done in order to present the probe in the identical frame in the same position on the computer screen, to maximise familiarity between stimuli and probe presentation (Geiselman & Bjork, 1980, cited in Mandler, 1980). However, this may have had counter-productive effects on the perceptual organisation of the stimuli, and, by association, the dissociative encoding of TBR and TBF sets. Jiang et al. (2000) found that in a visual change-detection task, the time taken to determine whether a target had changed colour was shorter if it was presented in a repeated spatial configuration than a new array. This indicates that spatial locations are encoded in configuration to one another. Applying this observation to Experiments 1A and 1B, responses may have been confounded by the fact that TBR and TBF sets were presented in the same array, thereby causing participants to encode all locations into a single configuration, irrespective of colour markers. By association, this may have made it difficult for participants to selectively rehearse the TBR set only, once the forget command had been administered. If this is the case, it is not clear what strategies participants might have employed during their responses.

Finally, it is plausible to argue that due to the formation of stable long-term memory representations in the learning condition, memory traces corresponding to the presented locations may have remained constantly activated throughout the experiment, rather than deteriorating in between trials. In other words, it is possible that across trials, some transient memory trace remained activated corresponding to all test items, thereby interfering with any dissociation between probes based on familiarity. Indeed, the fact that response times in the learning condition were equivalent to all three probe types would support this theory. The fact that there was no change to the visual presentation of the test items and the probe (i.e. the position of the grid containing the test items was identical with the position of the grid containing the probe) might have elevated this problem.

Thus, in the following experiment, the two sets of spatial locations were presented in two separate frames on the computer screen to reinforce a dissociation of the TBR and TBF locations. The probe was presented in a single frame in the middle of the screen. It was hoped that forcing participants to mentally shift the configuration into a different position on the screen at test might reduce the possibility that pre-existing long-term memory representations would thwart the decay of already presented locations in previous trials.

(2.3) Experiment 1C

There were no design changes between Experiments 1B and 1C, with one important exception: TBR and TBF location sets were presented in two separate frames. This was done to facilitate the ability to selectively rehearse the TBR item throughout the retention period. The grids in the two frames were identical with the grid used in Experiment 1B, and the test stimuli were drawn from the same fixed location subset. The probe was shown in a single frame in the centre of the screen. Furthermore, rather than cuing the TBR set by changing the entire screen into either blue or orange, the two grids in which the TBR and TBF configuration had previously been shown remained visible, and only the area around the two frames changed into blue or orange. This was done to allow participants to use the grid as a frame of reference for rehearsing the TBR items, in an effort to compensate for the potential loss of familiarity of the TBR set that might have been created by presenting the stimuli in a different position on the screen at test time. Similar to Experiment 1B, one group of participants learned all the possible test locations prior to the experiment, whereas those assigned to the control group only participated in the main memory task (see Figure 11, p. 82).

If the training session can create long-term memory traces strong enough to sustain until the end of the experiment, and if the intrusion cost occurs because the decay of TBF traces is prevented through long-term memory support, then only the learning condition should yield a significant intrusion cost. No such long-term memory representations should have been created in the control group. Hence, no intrusion costs should be observed in this condition. To test this hypothesis, an emphasis was again placed on a comparison of response times to TBF and control probes in both conditions.

(a) Method

(i) Participants

46 undergraduate students from the University of Plymouth participated in exchange for course credit or small monetary payment. All participants had normal or corrected to normal vision. In the learning condition, 2 participants had an accuracy score below 40% and were therefore subsequently dropped from any further analyses. In the control condition, one participant was excluded from the analysis, due to a failure of the computer program halfway through the experiment. For three participants, accuracy was below 40%, and they were also not considered for analysis. In the final analysis, 20 participants were included in each condition.

(ii) Materials

The data was collected by a program coded in E-prime (see above), presented on a 17" monitor, set as previously to a resolution of 1024 x 768 pixels. The stimuli were presented in two separate frames (approximately 21 cm wide, 10.4 cm high) presented on top of one another on the computer screen. Each frame contained the grid already described in Experiment 1B (Figure 9, p. 73). The probe was presented in the same grid in a single frame in the centre of the screen. For the training session in the learning condition, paper replicas of the grid were produced that participants needed to fill in.

(iii) Procedure

This experiment used a 2 (learning versus control condition) x 3 (TBR, TBF or control probe) mixed subjects design. Equal amounts of participants were assigned to the learning and control condition.

Pre-test training session: The training session was identical to Experiment 1B.

Main memory task: The main memory task was identical in both control and practice condition, and was also identical to the task used in Experiment 1B, with the following exceptions: TBR and TBF stimuli were presented in two separate grids integrated in two separate frames on the computer screen (see Figure 11, p. 82). Stimuli were selected so that there was no positional overlap between the two frames (e.g. if position A was occupied in the top frame, it would not be occupied in the lower frame). The order in which upper and lower frame contained orange or blue squares was randomised across the experiment. Once the presentation phase was over, the frames including the integrated grids remained on the screen, while the orange and blue colour markers disappeared. Around the two frames, the screen then changed into either blue or orange, thereby indicating whether participants had to remember the blue or orange locations. Cue presentation was lengthened from 1000 to 1300 ms with no visual mask separating cue and probe. This was done to allow participants more time to rehearse the TBR items with the aid of the grid. At test, participants saw a single framed grid with one location highlighted in black. As before, they needed to judge whether this was a location from the TBR set; pressing "y" if they thought it was, and "n" if they thought it was not. Once a response had been made, feedback (see previous experiments) appeared on the screen for 1500 ms. After 1000 ms, the next trial was initiated.

Post-test verification task: The post-test verification task was identical to Experiment 1B.

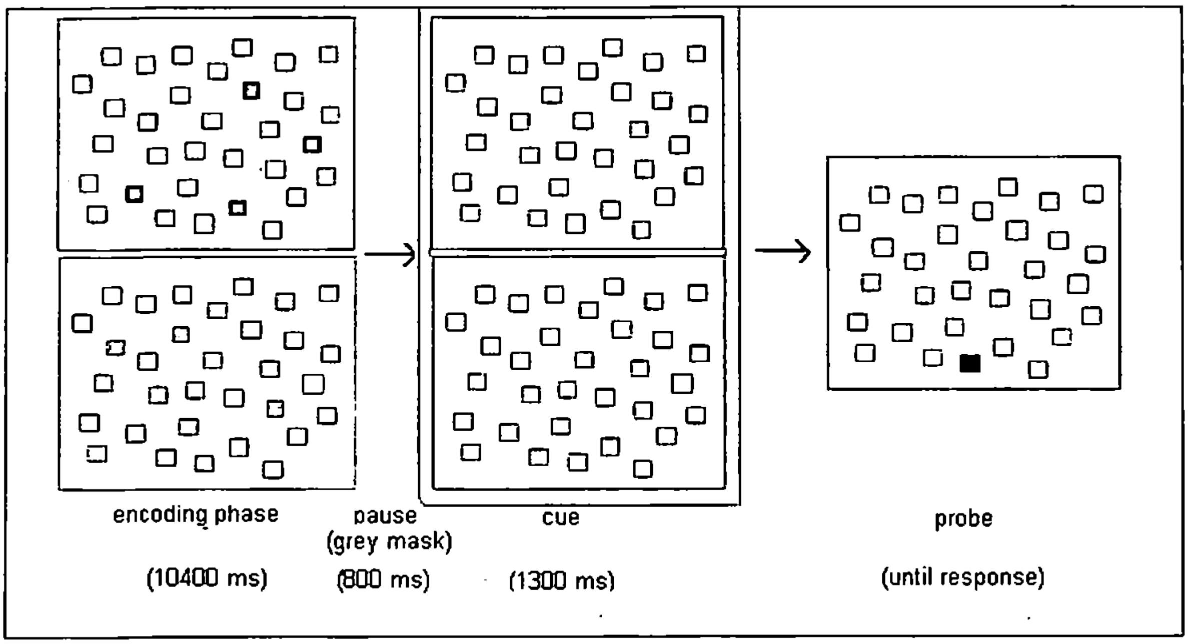

Figure 11: Basic methodology of main memory task in Experiment 1C. Similar to earlier experiments, participants studied two sets of spatial locations coloured in either orange or blue, this time presented in two separate frames (in previous experiments, the two sets were presented in one frame). Subsequently, the area around the two grids changed into either blue or orange to cue the TBR locations. At test, participants judged whether a single location probe had been a TBR location. In this example, the correct answer is "yes".

(b) Results

In the learning condition, all participants completed the training session successfully and were also able to recall the 12 test locations in the post-test recall task. A 2 (condition type) x 3 (probe type) mixed ANOVA was carried out to explore accuracy scores and median response times. As before, a priori predictions dictated that post hoc analyses would be carried out to assess the presence of an intrusion cost or intrusion error.

EXPLORING THE FATE OF NO LONGER RELEVANT SPATIAL INFORMATION USING A MODIFIED STERNBERG TASK

KIRSTEN BURGHARDT

ABSTRACT

Previous research into deliberate forgetting has primarily been carried out with verbal material. In a modified Sternberg task, Oberauer (2001) found longer response times when rejecting no longer relevant probes relative to control probes. This "intrusion cost" was seen as evidence that no longer relevant material remains activated in memory, thereby triggering a familiarity signal that must be overwritten by recollection processes to reject the probe as not to-be-remembered.

Using a modified nonverbal Sternberg task, the aims of the studies presented in this dissertation were to investigate (1) whether similar processes could be observed in nonverbal memory, and (2) whether the familiarity signal underlying the intrusion cost is solely based on long-term memory traces. Results suggested that, at least in nonverbal memory, the intrusion cost may not entirely be driven by long-term memory, but that perceptual processes may also be involved. Findings were discussed in light of the debate on the dissociation of verbal and nonverbal memory, as well as current working memory models and our understanding of deliberate forgetting.

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(i) Median response times analysis

There was a main effect of probe type ($F_{2,76}$ = 6.7, *MSe* = 25218.7, *p* = 0.002). LSD tests suggested that overall, responses were slower to TBR probes (*M* = 1046.9 ms, *SD* = 247.7) than to TBF probes (*M* = 949.0 ms, *SD* = 222.6; p = 0.012) and control probes (*M* = 924.1 ms, *SD* = 211.9; *p* = 0.003). There were no differences between control probes and TBF probes (p = 0.405).

Learning effects. There was no significant main effect of condition – performances were comparable in the learning and control condition ($F_{1,38}$ = 0.6, *MSe* = 107248.2, *p* = 0.434), and there was also no significant interaction between probe type and condition ($F_{2,76}$ = 0.4, *MSe* = 25218.7, *p* = 0.714). These results indicated that participants performed similarly regardless of the condition that they had been assigned to (see Figure 12, p. 84).

Intrusion costs. In the learning condition, participants were faster to reject control probes than TBF probes (*p* = 0.025; main effect of probe type: $F_{1.4,\,26.8}$ = 10.1, *MSe* = 15313.1, *p* = 0.002). In contrast, no such observable response lag differences were found in the control condition (*p* = 0.966; main effect of probe type: $F_{2,38}$ = 1.7, *MSe* = 39635.7, *p* = 0.193).

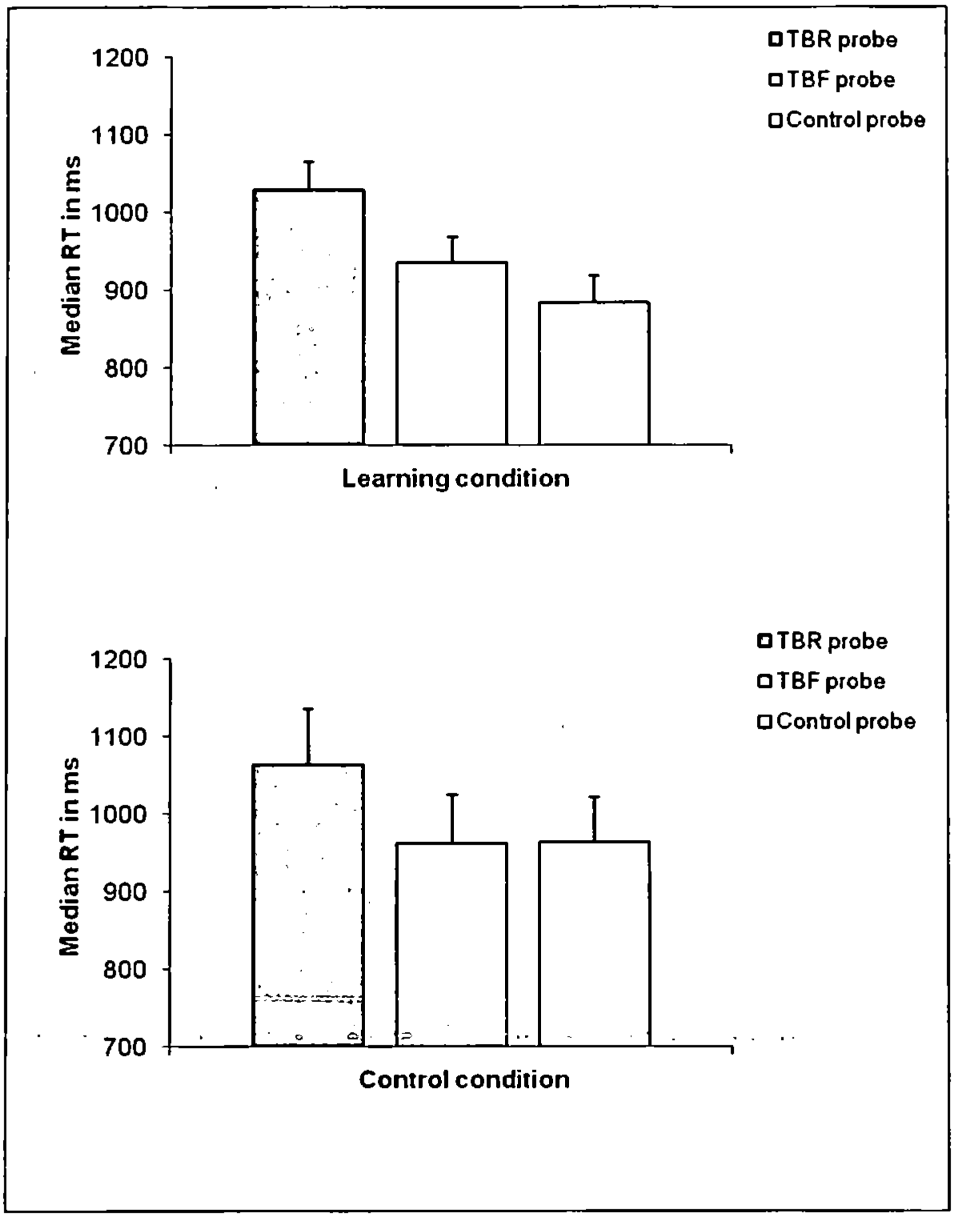

Figure 12: Median response times data in Experiment 1C, with error bars representing one standard error of the mean. In the control condition, no intrusion cost emerged – response times were virtually identical for TBF and control probes. Participants who had been involved in the training session, however, took significantly longer to reject TBF probes than control probes, thereby producing an intrusion cost.

(ii) Accuracy analysis

There was a significant main effect of probe type ($F_{2,76}$ = 6.0, *MSe* = 130.6, *p* = 0.004). LSD tests showed that performance was poorer when participants had to recognise a TBR item (*M* = 69.8%, *SD* = 12.3) in comparison to rejecting a control probe (*M* = 78.7%, *SD* = 12.4; *p* = 0.003). No significant accuracy differences emerged between TBR and TBF probes (*M* = 73.5%, *SD* = 14.8; *p* = 0.159). Participants rejected control probes more accurately than TBF probes (*p* = 0.035).

Learning effects. The main effect of condition was not reliable ($F_{1,38}$ = 2.6, *MSe* = 250.5, *p* = 0.115), and there was no observable interaction between probe type and condition ($F_{2,76}$ = 1.5, *MSe* = 130.6, *p* = 0.223), indicating comparable performance patterns in the two conditions (see Figure 13, p. 86).

Intrusion errors. In the learning condition, there was a significant main effect of probe type ($F_{2,38}$ = 5.2, *MSe* = 142.3, *p* = 0.010), but this was not the case in the control condition ($F_{2,38}$ = 2.0, *MSe* = 118.9, *p* = 0.143). Numerically, performance was poorer in response to TBF than control probes in both conditions, but this did not reach significance (*p* = 0.204 and 0.095 in learning and control condition, respectively).

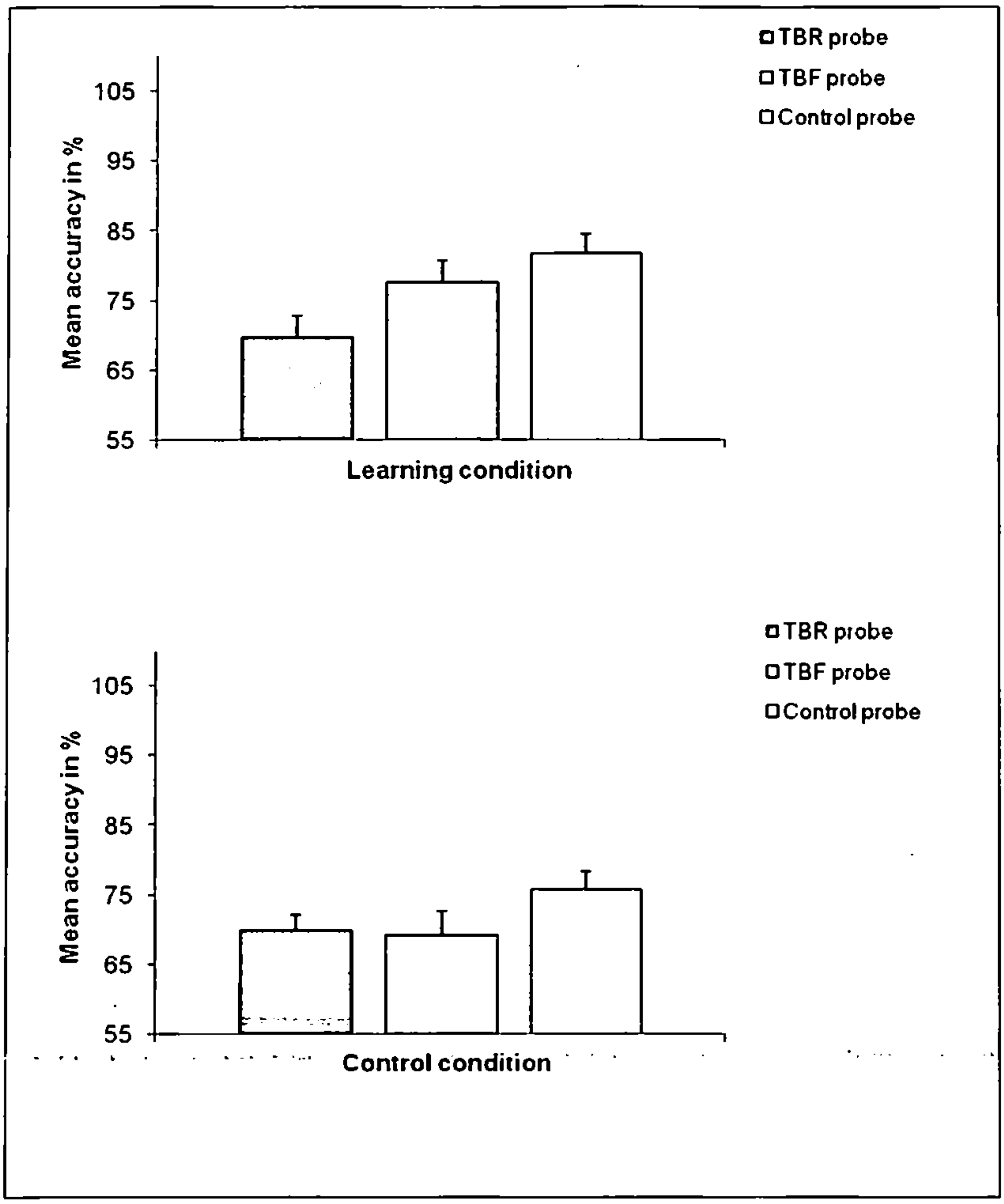

Figure 13: Mean accuracy in Experiment 1C. Error bars represent one standard error of the mean. In both conditions, performance was numerically poorer in response to TBF probes than control probes, but this did not reach significance. Evidence for an intrusion error was therefore not found. There were no observable performance differences between the learning and control condition.

(c) Discussion

In Experiments 1A and 1B, no intrusion cost emerged regardless of training manipulations to increase the stability of long-term memory traces corresponding to the test items. In this experiment, the selective maintenance of the TBR stimuli was encouraged by visually segregating the presentation of TBR and TBF location sets. For the first time, an intrusion cost was observed in the learning condition. Furthermore, even though this did not reach significance within each condition, accuracy was overall poorer in response to TBF than control probes. Only the control condition displayed performance patterns that were comparable to what was observed in previous experiments.

Such an outcome supports Oberauer's account of the intrusion cost: Following the "forget" command, no longer relevant memory traces that form a stable part of long-term memory are no longer attended to but remain sufficiently activated to trigger a familiarity signal when a TBF probe is presented. This familiarity signal needs to be overwritten to accurately reject the probe as not to-be-remembered. A control probe is not represented by an activated memory trace and can therefore be rejected relatively quickly. In the control condition, participants had not formed consistent representations of the test items in long-term memory prior to the experiment. Without such long-term memory support, this presumably led to the rapid decay of the memory traces corresponding to the TBF items once the forget cue had been given. As a consequence, TBF probes could not trigger a familiarity signal, and they were therefore rejected with the same speed as control probes.

Even though the training manipulation appeared to have an effect on response times differences between TBF and control probes, performance levels in learning and control condition were virtually identical in response to TBR probes. Comparable to Experiment 1A and 1B, performance was again poorer with TBR probes than negative probes. Such an observation is potentially at odds with findings by Hulme and colleagues (1991; Hulme et al., 1995), who found that memory for items increased if they were firmly represented in long-term memory relative to items that did not reside in long-term memory. However, the material used by Hulme et al. typically involved English vocabulary for which participants presumably held much stronger long-term memory representations than those created in the short training session prior to Experiment 1C. Perhaps, in order to observe clear beneficial effects of long-term memory on the direct recall of information, much larger discrepancies are required between the levels of long-term memory representations in the learning versus control condition.

Thus, the results in Experiment 1C provide support for the view that performance in working memory tasks can be modulated by long-term memory (e.g. Cowan, 1999; Hulme et al., 1995; Oberauer, 2001). In addition, these findings suggest that once the stimuli are matched in terms of long-term memory presence, it is possible to observe an intrusion cost both with verbal and nonverbal memory stimuli, which may potentially have implications for our understanding of the architecture of memory. However, without the replication of the intrusion cost under similar circumstances, any firm conclusion may be unsafe. Furthermore, while Experiment 1C successfully established an intrusion cost using nonverbal material, this does not in itself imply that the underlying processes of the effect were identical with those observed in verbal memory. The following experiments therefore explore whether the nonverbal intrusion cost found in Experiment 1C was driven by similar mechanisms as the verbal intrusion cost found by Oberauer (2001).

(2.4) Experiment 1D

Experiment 1C provided some evidence to support the view that the intrusion cost may be reliant on the support of long-term memory. Only those participants that had learned the test locations prior to the experiment exhibited slower response times to TBF than control probes. What remains unclear, however, is the underlying cause of this observation. Thus, the aim of Experiment 1D was twofold. It tested whether, given the same circumstances, the intrusion cost is a replicable phenomenon in nonverbal memory. Furthermore, it investigated whether the emergence of the intrusion cost is confined to those locations that participants have learned, or whether it would also carry over to other configurations on which participants had not been trained. This is an important investigation to eliminate the hypothesis that the training session may have merely served to improve participants' general skills in this type of nonverbal memory task, rather than having a localised effect on their performance with the specific locations that they had learned prior to testing.

To this end, Experiment 1D involved the use of two location sets (A and B). Participants were trained on location set A only, but throughout testing, blocks of trials were presented with location set A and B. If the training manipulation simply improves participants' general ability to execute the task, and if this is the underlying reason for the intrusion cost, then comparable performances should be measured with both location sets. If, on the other hand, effects of the training manipulation are confined to the specific locations on which participants have been trained, then the intrusion cost should only emerge in trials presenting location set A.

Should the intrusion cost be replicated with the trained location set only, this would strengthen the argument that the training session creates long-term memory representations of the test items, thereby preventing a rapid activation decay of a TBF memory trace once attention is focused on the rehearsal of task-relevant material. If, on the other hand, the effects of training carry over to other configurations as well, this would indicate that any performance changes are not necessarily due to the formation of long-term memory representations corresponding to the stimuli, but that the training session merely alters participants' general ability to encode and maintain the nonverbal stimuli in this task.

To test these competing hypotheses, a specific emphasis was once more placed on an analysis of response times to detect any intrusion cost effects in trial blocks with location set A versus location set B.

<u>(a) Method</u>

(i) Participants

15 participants, mostly undergraduate students from the University of Plymouth, took part in this study for either course credit or monetary rewards. Participants were not colour-blind and reported normal or corrected-to-normal eyesight.

(ii) Materials

Most of the material was the same as used in Experiment 1C. Location set A (on which participants were trained) was identical to the set used in the previous experiment (see Figure 7, p. 69), and the training manipulation also involved the same material. A new grid was designed for location set B (see Figure 14, p. 91).

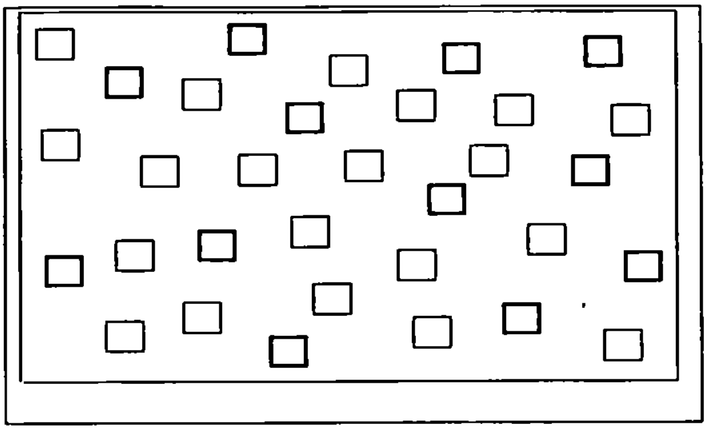

Figure 14: In Experiment 1D, blocks of trials presented frames with either location set A (Figure 7, p. 69) or location set B (presented here). Note that test items were selected only from the black squares (the same is true for location set A shown in Figure 7). In line with Experiment 1C, each trial showed the TBR and TBF stimuli in two identical matrixes presented on top of one another, i.e. either two "location set A" matrixes or "two location set B" matrixes with the TBR and TBF stimuli highlighted in blue or orange (see Figure 11, p. 82).

(iii) Procedure

This study involved a 2 (location set: A versus B) x 3 (probe type: TBR, TBF, or control probe) repeated measures-design.

Pre-test training: This was identical to Experiment 1C. All participants took part in this session.

Main task: The procedure in this study was identical with Experiment 1C, although, due to a programming oversight, the delay between stimuli and probe presentation was shortened from 1300 to 1000 ms with no grey visual mark separating colour cue and probe. Participants studied two framed grids presented on top of one another, one containing four squares highlighted in blue, the other containing four squares highlighted in orange. After 10400 ms, the colour markers within the grid disappeared, and the area around the frames changed into either blue or orange, thereby indicating whether participants had to remember the orange or blue configuration. At test, a single framed grid was presented in the centre of the screen, with a single location coloured in black. Participants judged whether this was a location that they had to remember, pressing "y" on their keyboard if they thought it was, and "n" if they thought it was not. They received immediate feedback (1500 ms) before the next trial was initiated after a 1000 ms pause.

The experiment comprised a total of four trial blocks (two blocks per location set) with 45 trials each (15 trials per probe type). The order of the blocks was randomised across participants. In addition, participants took part in four practice trials to accustom themselves to the procedures of the experiment.

Post-test verification task: All participants completed this task which was identical to what was carried out in Experiment 1C.

(b) Results

All participants successfully completed both pre-test training and post-test verification task, demonstrating that they had retained the principal test locations throughout the experiment. Accuracy and median response times were analysed using a 2 (location set: trained versus untrained) x 3 (probe type: TBR, TBF or control probe) repeated measures ANOVA.

(i) Median response times analysis

A significant main effect of probe type was detected across location sets ($F_{1.1, 15.6}$ = 11.9, MSe = 98181.6, p = 0.003). LSD comparisons showed that overall, responses were slower to TBR (M = 1247.4 ms, SD= 392.1) than to TBF (M = 1014.3 ms, SD = 193.1; p = 0.008) and control probes (M = 974.5 ms, SD = 188.9; p =

0.002). The response times difference between TBF and control probe just missed significance (p = 0.076).

Location set comparisons. Comparable to what was found with accuracy, there was no main effect for location set ($F_{1, 14}$ = 0.07, *MSe* = 59799.1, p = 0.795), but the interaction between probe type and location set was not reliable ($F_{1.2, 16.5}$ = 0.6, *MSe* = 34155.2, p = 0.479), suggesting that performance patterns were similar regardless of location set (see Figure 15, p. 94).

Intrusion Costs. In spite of the failure to detect a significant interaction, post hoc analyses were carried out to measure any observable intrusion cost. Certainly the graph (see Figure 15, p. 94) gave some indication that results in line with predictions may have occurred. With untrained locations ($F_{1.2, 16.4}$ = 14.1, *MSe* = 23335.9, p = 0.001), response times to TBF and control probes were virtually identical (p = 0.997). In trials using the trained location set ($F_{1.1, 15.5}$ = 6.5, *MSe* = 92999.0, p = 0.020), participants rejected control probes quicker than TBF probes (p = 0.014).

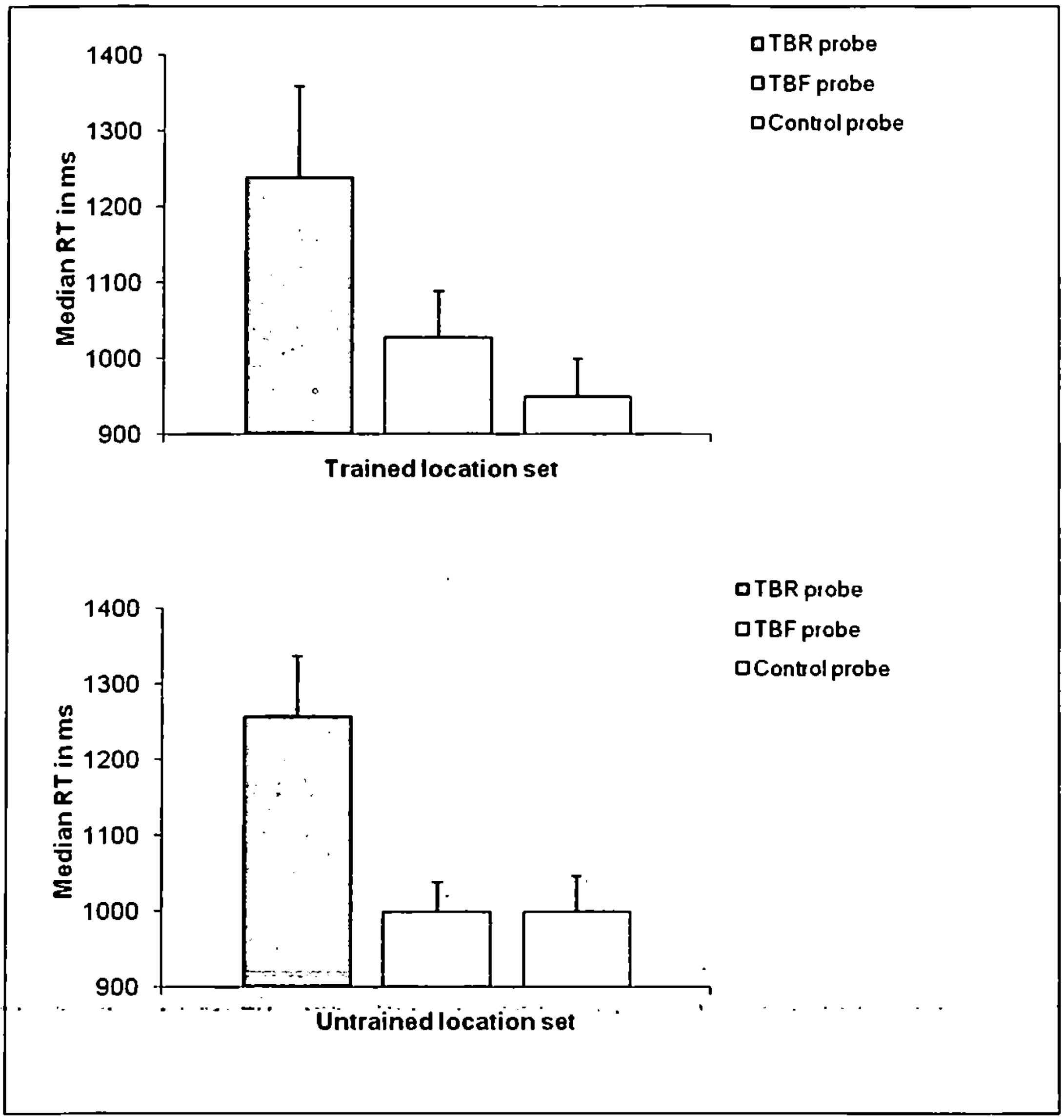

Figure 15: Median response times (error bars represent 1 standard error of the mean) in trained versus untrained location set (Experiment 1D). The graphs show evidence for an intrusion cost in trials using the trained location set only – here, response times were significantly longer with TBF than control probes. This was not the case in trials presenting the untrained location set.

(ii) Accuracy analysis

Overall, there was a reliable main effect for probe type ($F_{1.3, 18.6}$ = 15.6, *MSe* = 446.3, $p < 0.001$). Across location sets, LSD tests show that participants' accuracy was lower with TBR (M = 62.4%, SD = 17.8) than TBF (M = 81.4%, SD = 9.3; p = 0.002) and control probes (M = 85.8%, SD = 10.4; p = 0.001), with no performance differences between TBF and control probes (p = 0.091).

Location set comparisons. The main effect of location set was not significant ($F_{1,\ 14}$ = 0.042, MSe = 65.6, p = 0.8). However, there was a significant interaction between probe type and location set ($F_{2,\ 28}$ = 19.9, MSe = 51.2, p < 0.001, see also Figure 16, p. 96), suggesting that performance patterns across the three probe types were different depending on the location set that was used.

In trials using the trained location set, the main effect of probe type was reliable ($F_{1.4,\ 20.1}$ = 4.1, MSe = 235.7, p = 0.043). LSD tests suggested that participants were less accurate in response to TBR than control probes (p = 0.033) and TBF probes, although this outcome just missed significance (p = 0.06).

With the untrained location set, there was also a significant main effect of probe type ($F_{1.3,\ 17.9}$ = 27.7, MSe = 278.3, p < 0.001). Again, accuracy was lower with TBR than TBF (p < 0.001) and control probes (p < 0.001).

Intrusion errors. No significant differences were found between control and TBF probes (p = 0.9) in trials using the trained location set ($F_{1.4,\ 20.1}$ = 4.1, MSe = 235.7, p = 0.043). With the untrained location set ($F_{1.3,\ 17.9}$ = 27.8, MSe = 278.3, p < 0.001) , accuracy was higher with control than TBF probes (p = 0.006).

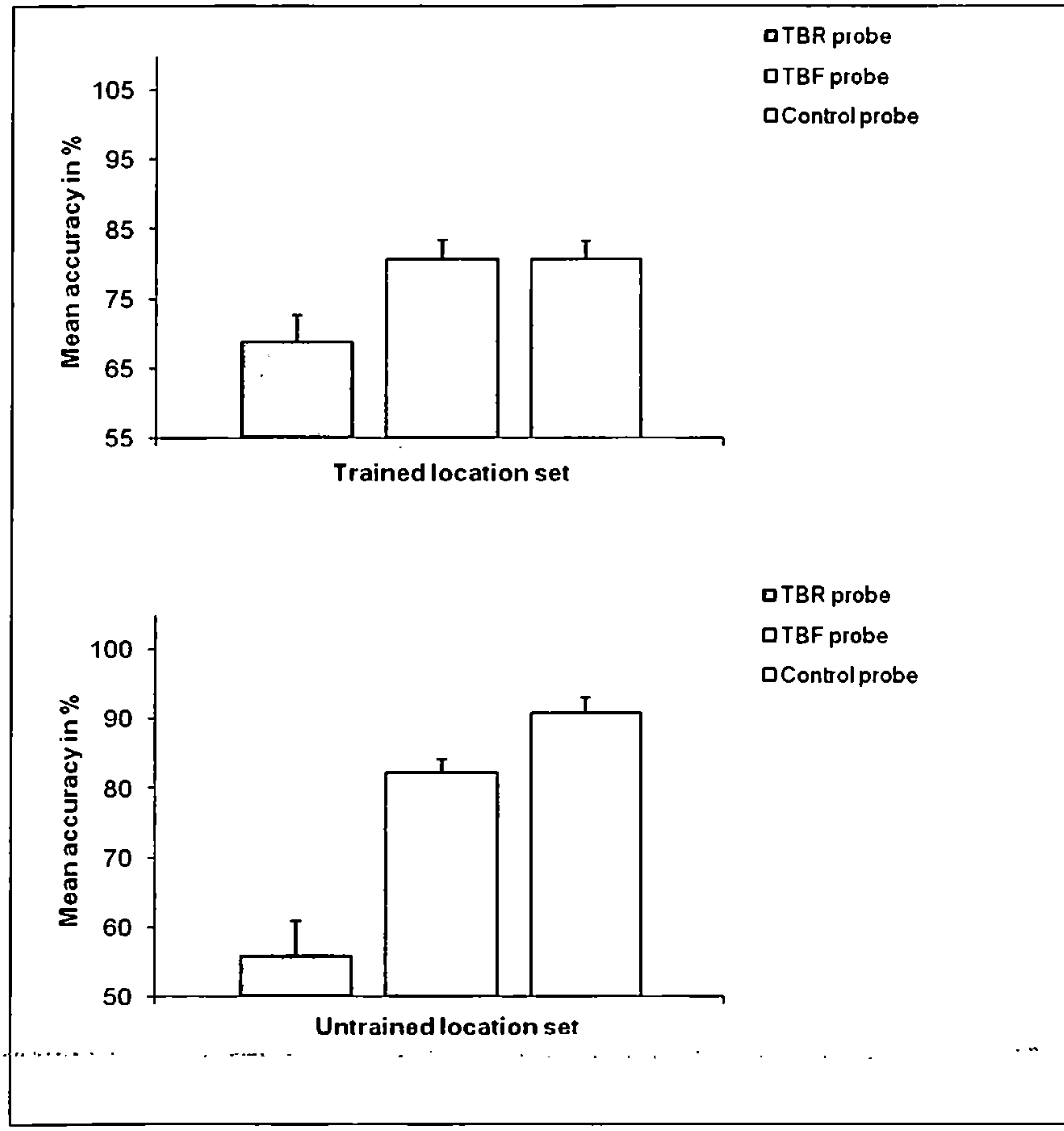

Figure 16: Mean accuracy in % (error bars represent 1 standard error of the mean) with trained and untrained locations in Experiment 1D. An intrusion error (higher accuracy with control than TBF probes) emerged in trials presenting the untrained location set only.

(c) Discussion

Experiment 1D explored the underlying reason for the emergence of an intrusion cost when participants memorise the test stimuli prior to testing. It investigated whether performance changes were confined to the configuration that participants had learned, or whether they would also translate to other location sets.

In addition, it was explored whether the intrusion cost is a reliable and replicable effect with nonverbal stimuli.

In line with a priori predictions, the intrusion cost surfaced only in those trials that presented the trained location set. Other results also support the notion that the training session had an item-specific effect: Accuracy in response to TBR probes was higher with trained locations than untrained locations, suggesting that participants found it easier to rehearse and retrieve items for which they had stable representations in long-term memory.

That the intrusion cost was confined to the trained location set supports Oberauer's (2001) argument that this phenomenon relies on the existence of activated long-term memory traces corresponding to the no longer relevant material decaying only gradually over time. In trials using the location set that participants had not learned before the experiment, no intrusion cost was found, suggesting that here, no TBF memory traces remained sufficiently activated to trigger a familiarity signal in need of overwriting. In addition, the finding that accuracy was higher with those TBR probes that participants had learned prior to testing suggests that memory maintenance is easier when the TBR stimuli are already represented in long-term memory.

However, other results contradict this picture. For example, the failure to find a significant interaction between probe type and location set in the response times data suggests that on the whole, there were no real performance differences between the two location sets. While the intrusion cost (prolonged response times to TBF probes relative to control probes) was confined to the trained location set, the opposite picture emerged in the intrusion errors analysis: Participants were in fact more accurate with control than TBF probes in trials using the untrained location set only.

This pattern appeared to be primarily due to higher accuracy with control probes in the untrained relative to the trained location set, while accuracy with TBF probes remained comparable between the two sets.

It is not clear why this occurred, but there are several possible interpretations. One might argue that control probes were rejected more accurately with the untrained than trained location set because of a criterion shift. Trials not showing locations that participants had learned may have been much harder, making participants more inclined to reject the probes as not to-be-remembered. That performance with TBR probes dropped to almost chance (56%) in the untrained condition would support this argument. However, accuracy with TBF probes remained identical in the trained and untrained condition – if participants had undergone a complete criterion shift towards rejecting a probe, then accuracy should have improved for both control and TBF probes in the untrained condition.

Another potential explanatory factor could be that in each trial, stimuli and probes were selected from a fixed set of locations. Thus, in any one trial, the control probe may have been a TBR or TBF location in a previous trial. If training strengthened the resilience of memory traces corresponding to each test location, perhaps, once such a trace had been activated in a previous trial, some of this activation may have transferred across trial boundaries. Such remaining activation then may have produced a familiarity signal, thereby contaminating participants' response to the control probe. This in turn may explain why performance with control probes was stronger with the untrained location set, where no previous knowledge (and thus memory trace) of the stimuli existed to prevent a rapid decay of the used stimuli once a trial cycle had been completed. One counter-argument to this view would be that if the familiarity of locations cut across trial boundaries, this should have affected all three probe types, thereby creating similar performances to all of them in the trained location set. This was, however, not the case. It is therefore not clear why participants rejected control probes more accurately with trials showing the untrained location set.

In summary, the interpretation of Experiment 1D remains somewhat inconclusive, suggesting that training may have well had an impact on participants' overall performance in this type of task alongside more item-specific effects confined to the trained location set. That the training session had an effect irrespective of location set was perhaps to be expected, since it may have given participants the opportunity to develop processing strategies for memorising and retrieving locations that could be applied to any type of grid used in this study. Important for the following experiments was the replication that the intrusion cost only occurred with locations that participants had memorised prior to testing, but it did not emerge with locations that participants had not learned. This offers some support for the notion that in nonverbal memory, the intrusion cost surfaces reliably only when participants had familiarised themselves with the material prior to testing.

The past two experiments provided some evidence to suggest that comparable to verbal memory, no longer relevant nonverbal memory traces can remain sufficiently activated for some time to still trigger an intrusion cost. In his model, Oberauer (2001) argued that once an item is declared irrelevant and its rehearsal is abandoned, its corresponding representation is transferred to the activated subset of long-term memory, where it is no longer readily available but decays only gradually, thereby still triggering a familiarity signal if the item is represented. Evidence for this view is the finding that only the size of the TBR set affects response times and accuracy, suggesting that only the TBR memory traces reside in the capacity-limited direct access region (Oberauer, 2001). Thus, even though TBF probes still trigger an intrusion cost (suggesting the corresponding memory trace has not been entirely erased from memory), the TBF set size does not influence performance. This finding supports Oberauer's notion that no longer attended to memory traces form part of the activated subset of long-term memory, rather than the direct access region.

The following experiment explored if the same results could be observed with nonverbal information. This is potentially an important investigation, because it sheds light on the question whether Oberauer's model really can account for processes both in verbal and nonverbal memory.

Similar to Oberauer's study, Experiment 1E included a manipulation of the size of the TBR and TBF sets. Participants either studied 2 or 4 TBR locations in combination with 2 or 4 TBF locations. To ensure that the intrusion cost would reemerge, a training session once more preceded the main memory task. An intrusion cost was predicted, but at the same time, it was also predicted that only the TBR set size should have an impact on performance. This would be comparable to what was found in the verbal domain (Oberauer, 2001), where, once a stimulus is declared task-irrelevant, its representation is transferred into the activated subset of long-term memory where its activation decays only gradually, allowing an intrusion cost to occur.

(2.5) Experiment 1E

(a) Method

(i) Participants

27 undergraduate students from the University of Plymouth took part in this study in exchange for course credit. All participants reported normal or corrected-to-normal

eyesight and no colour blindness. Due to poor accuracy, 3 participants were subsequently dropped from the data set, leaving a total of 24 participants.

(ii) Material

The materials used in this study were identical with those in Experiment 1C.

(iii) Procedures

This study involved a 2 (size of the TBR set: 2 or 4 items) x 2 (size of the TBF set: 2 or 4 items) x 3 (probe type: TBR, TBF or control probe) repeated measures design.

The overall procedures of the study were the same as reported in Experiment 1C, save for a few adjustments: Throughout, the size of TBR and TBF locations were systematically manipulated: Participants studied either 2 or 4 TBR items in combination with either 2 or 4 TBF items. 45 trials (15 per probe type) were devoted to each set size combination, accumulating to a total of 180 trials. The use of different set sizes was randomised in an unpredictable fashion across the study. Stimuli presentation length was adjusted to the amount of items that participants needed to learn (1300 ms per item). As before, participants studied two framed grids containing four locations highlighted in blue or orange. After the colour markers had disappeared from the grid, the area around the frames changed into either blue or orange, cueing participants to remember either blue or orange locations. This was followed by the presentation of a single grid with one location highlighted in black. When participants thought that this was a TBR location, they selected "y" on their keyboard, if not, they selected "n". Feedback was given after each trial. The experiment was preceded by four practice trials familiarising participants with the procedure.

(b) Results

All participants performed both pre-test training and post-test verification task successfully. The collated data was analysed using a 2 (TBR set size: 2 or 4 items) x 2 (TBF set size: 2 or 4 items) x 3 (probe type: TBR probe, TBF probe, control probe) repeated measures ANOVA. As before, only those results deemed relevant are mentioned here, for further analyses please consult Appendices.

(i) Response times

The main effect of probe type was highly significant ($F_{2, 46}$ = 14.6, *MSe* = 37216.3, $p < 0.001$), although this was mainly due to participants' slow response times to TBR probes (*M* = 1003.4 ms, *SE* = 54.4) in comparison to both TBF (*M* = 868.1 ms, *SE* = 45.2; $p < 0.001$) and control probes (*M* = 877.3 ms, *SE* = 44.4, $p < 0.001$). There was no significant difference in performance between TBF and control probes ($p = 0.669$).

On the whole, only the size of the TBR set had an impact on performance ($F_{1, 23}$ = 78.3, *MSe* = 14321.7, $p < 0.001$): Participants performed significantly faster when they only had to retain 2 (*M* = 853.9 ms, *SE* = 42.3), rather than 4 TBR locations (*M* = 978.6 ms, *SE* = 48.6). By contrast, response times were unaffected by the amount of presented TBF items ($F_{1, 23}$ = 0.194, *MSe* = 11616.8, $p = 0.664$). With the exception of a significant interaction between the sizes of TBR and TBF sets ($F_{1, 23}$ = 5.1, *MSe* = 13517.9, $p = 0.034$), there were no significant two-way or three-way interactions (see Appendices).

(ii) Intrusion costs

An important part of this investigation was to establish the existence of any intrusion costs. To this end (and in spite of the failure to find a significant three-way interaction between the set sizes and the probe types), each combination of TBR and

TBF set sizes was explored separately to determine whether an intrusion cost occurred. More detailed results of these analyses are presented in Appendices 5b-5e. As can be seen in Figure 17 (p. 105) as well as Table 3 (p. 107), no reliable response times differences were found between control and TBF probes in any of the set size conditions.

(iii) Accuracy

Comparable to what was found in the response times data, there was a significant main effect of probe type ($F_{1.6, 36.1} = 34.6$, $MSe = 214.5$, $p < 0.001$) – performance was significantly poorer in response to TBR probes ($M = 72.6\%$, $SE = 2.1$) than TBF ($M = 87.2\%$, $SE = 1.7$; $p < 0.001$) or control probes ($M = 84.6\%$, $SE = 2.2$; $p < 0.001$). There were no significance differences between TBF and control probes ($p = 0.101$).

Participants performed significantly better when they only needed to retain 2 TBR ($M = 85.7\%$, $SE = 1.5$) rather than 4 TBR items ($M = 77.2\%$, $SE = 2.1$), demonstrating that performance was particularly affected when the size of the TBR set was varied ($F_{1, 23} = 42.3$, $MSe = 123.7$, $p < 0.001$). A similar trend was observed with TBF items (2 TBF items: $M = 83.5\%$, $SE = 1.9$; 4 TBF items: $M = 80.3\%$, $SE = 1.7$), although here, this effect was much smaller and just missed significance ($F_{1, 23} = 4.2$, $MSe = 85.4$, $p = 0.053$). Thus, comparable to the observed pattern in the response times data, only the size of the TBR set had a significant impact on accuracy.

(iv) Intrusion errors

For a detailed breakdown of analyses of each set size combination, please refer to Appendices 5g-5j. Performance was comparable with control and TBF probes in all four set size conditions (see Table 3, p. 107, and Figure 18, p. 106).

Differences just missed significance when participants studied 4 TBR and 2 TBF locations, and when the trial included 4 TBR and 4 TBF locations. However, the direction of these differences was opposite to that predicted for an intrusion error.

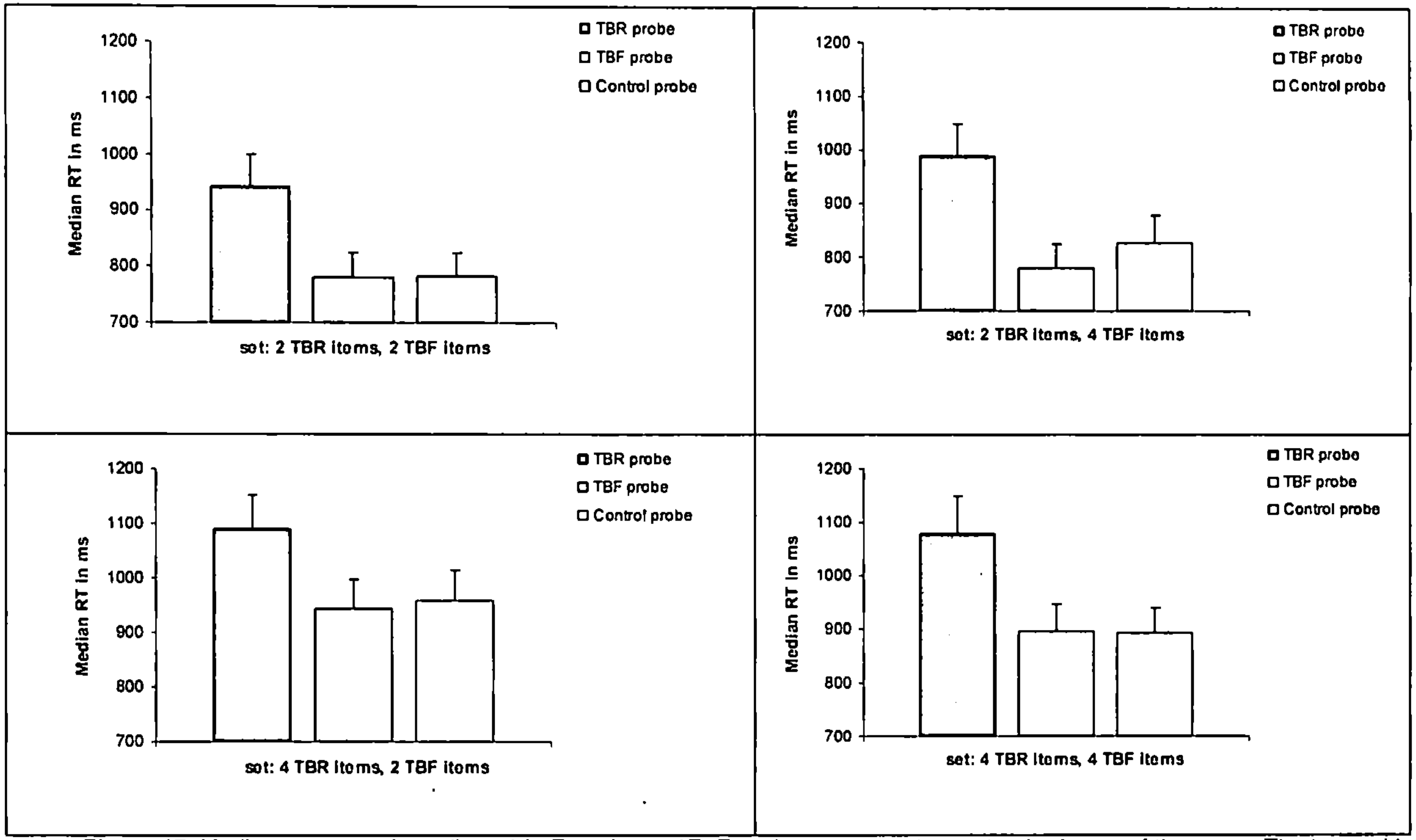

Figure 17. Median response times (in ms) in Experiment 1E. Error bars represent one standard error of the mean. The top and bottom rows compare response times with 2 and 4 TBF items (top row with 2 TBR items, bottom row with 4 TBR items), the left and right columns compare response times with 2 and 4 TBR items (left column with 2 TBF items, right column with 4 TBF items). Overall, response times were only affected by varying the size of the TBR set, but not the TBF set. No intrusion cost was observed in any of the conditions.

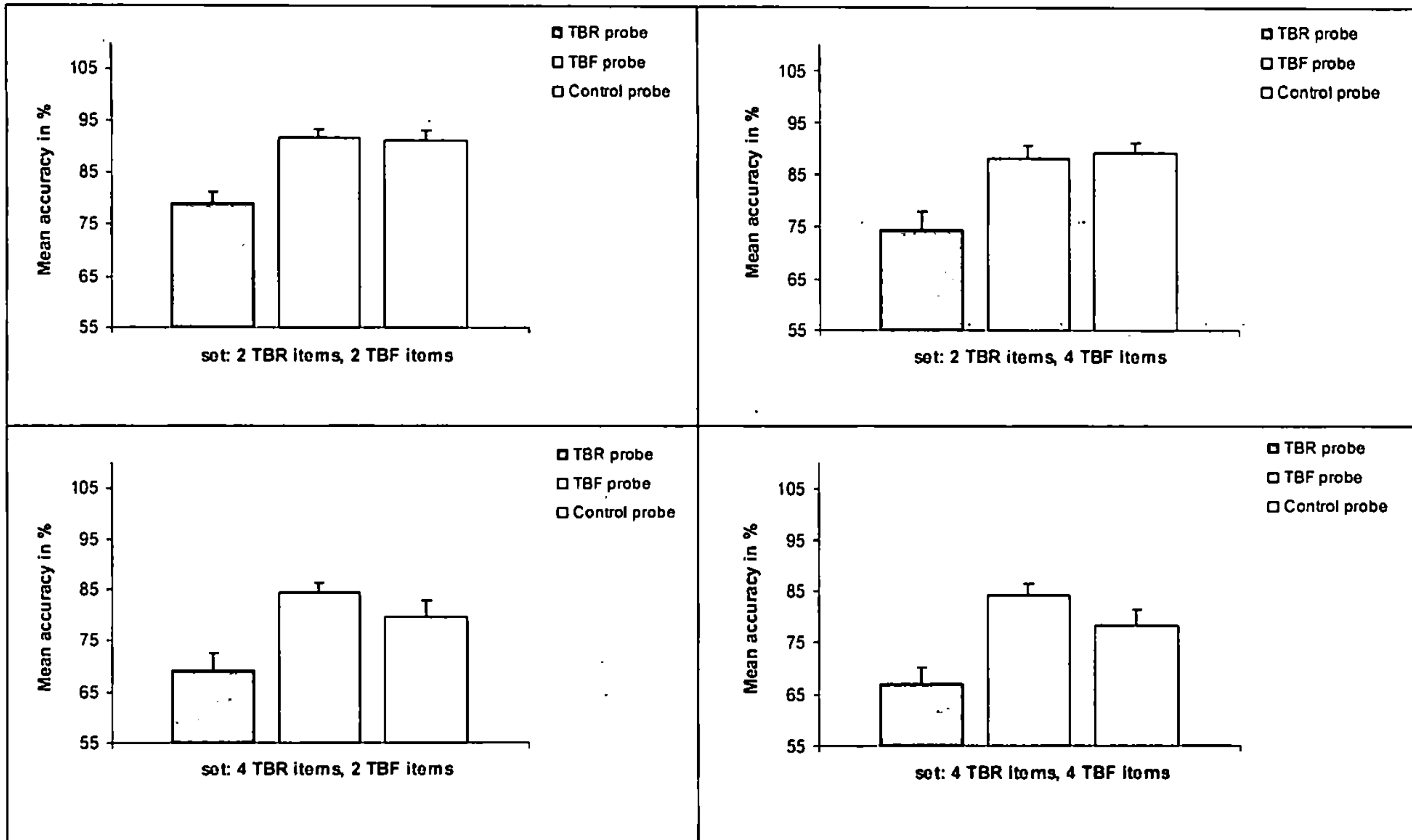

Figure 18. Mean accuracy (in %) in Experiment 1E. Error bars represent one standard error of the mean. The top and bottom rows compare performances with 2 and 4 TBF items (top row with 2 TBR items, bottom row with 4 TBR items), the left and right columns compare performances with 2 and 4 TBR items (left column with 2 TBF items, right column with 4 TBF items). No intrusion error occurred with any set size combination. Overall, performances were particularly affected by the size of the TBR set, but also by the TBF set size when the TBR set was held constant at 2 items.

Size of TBR and TBF sets	Main effect of probe type	Significance of intrusion error (accuracy)	Significance of intrusion cost (response times)
2 TBR/ 2 TBF	**RT:** $F_{1.5,\ 33.9}$ = 19.6, *MSe* = 14304.4, p < 0.001 **Accuracy:** $F_{2,\ 46}$ = 41.1, *MSe* = 29.1, *p* < 0.001	*p* = 0.715	*p* = 0.902
2 TBR/ 4 TBF	**RT:** $F_{1.6\ 36.5}$ = 16.2, *MSe* = 22137.9, *p* < 0.001 **Accuracy:** $F_{1.5,\ 35.4}$ = 10.1, *MSe* = 203.0, *p* = 0.001	*p* = 0.740	*p* = 0.098
4 TBR/ 2 TBF	**RT:** $F_{2,\ 46}$ = 4.1, *MSe* = 38368.0, *p* = 0.023 **Accuracy:** $F_{2,\ 46}$ =13.3, *MSe* = 110.1, *p* < 0.001	*p* = 0.054	*p* = 0.749
4 TBR/ 4 TBF	**RT:** $F_{2,\ 46}$ = 11.6, *MSe* = 23535.4, *p* < 0.001 **Accuracy:** $F_{2,\ 46}$ = 13.7, *MSe* = 130.1, *p* < 0.001	*p* = 0.070	*p* = 0.931

Table 3: Intrusion errors and costs (together with corresponding main effects of probe types) in Experiment 1E. There were no significant intrusion costs in any conditions, and marginally significant intrusion errors were found only with 4 TBR and 2 TBF items (*p* = 0.054) and 4 TBR and 4 TBF items (*p* = 0.070).

(c) Discussion

The results reported above provide good evidence that performance was affected by the amount of TBR material that participants needed to retain. Both accuracy and response times were negatively affected by a size increase of the TBR set. By comparison, the impact of the amount of TBF items was not as profound: Increasing the set size from 2 to 4 TBF items had no consequence on response times, and in the accuracy data, the main effect of increasing the TBF set size just missed significance. This is comparable to what was found in Oberauer's verbal memory study where performance was only affected by the amount of TBR items, while an increase of TBF words did not alter accuracy or response times. This replication supports Oberauer's interpretation that only TBR items remain within the capacity-limited direct access region, where an increase of retained material can reduce the quality of performance.

The relatively limited impact of the TBF set in this study could also be interpreted as a replication of Oberauer's results, were it not for one additional, more problematic finding: The failure to replicate the intrusion cost. Oberauer argued that the combination of an intrusion cost together with the lack of a TBF set size effect was evidence for the notion that TBF items remain available in the activated subset of long-term memory, where they still trigger an intrusion cost, but they are not readily accessible to consciousness. In this study, however, I was unable to detect an intrusion cost. Without this effect, it is tempting to interpret the minimal influence of the size of the TBF set as evidence that participants truly "forgot" the TBF locations.

Is this, however, a plausible explanation? It seems improbable to argue that participants can erase any trace of the TBF locations from their memory within a delay as short as 1300 ms (the delay between cue to forget and probe presentation). A further issue in need of addressing is why the training manipulation enabled a replication of the intrusion cost in a previous study, but failed to do so again here. To briefly recap, the previous two studies suggested that whether TBF material remains activated in memory over time depends on the strength of its representation in long-term memory. By enhancing the degree to which participants were familiar with the test material through prior practice, I was able to discover an intrusion cost in Experiments 1C and 1D. It is not clear why the intrusion cost did not occur in this study, since (apart from the set size manipulation and the amount of trials) it entailed an exact replication of the training condition in the two previous experiments, including an identical location set and the same training procedures. A more detailed review of the nonverbal intrusion cost as well as the results of this study will be provided below, followed by a rationale that inspired the next series of experiments reported here.

(2.6) Series 1: Overall Discussion

Up until this point, the primary aim of this thesis has been to discover if nonverbal material that is no longer attended to can leave a trace strong enough to trigger an intrusion cost. Only few studies have looked at directed forgetting in nonverbal memory (Cornoldi & Mammarella, 2006, Palladino et al., 2003), mostly with inconclusive results regarding the underlying processes. The task implemented in this PhD used nonverbal material that participants had not encountered before, and thus for which they did not have any pre-existing long-term memory representations. Experiments 1A-1E explored whether an intrusion cost can only emerge if the participant is already familiar with the test stimuli. Oberauer's explanation of the intrusion cost relied on the premise that the TBF information is represented by strong, resilient traces in long-term memory, traces that will then decay only gradually once attention is deployed elsewhere. With stimuli that an individual does not experience on a regular basis in everyday life (such as those used here), it is plausible to argue that such material would not leave a memory trace with the same resilient strength as the verbal information (words of high frequency) used in Oberauer's (2001) study. Therefore, an intrusion cost should not occur.

Experiment 1A indicated that implicit memory traces of the test items were not sufficient for the emergence of an intrusion cost. However, results in Experiment 1B and 1C showed that part of the failure to find an intrusion cost in the first study may have been due to the fact that the combined presentation of TBR and TBF locations in the same frame might have prevented participants from selectively rehearsing the TBR locations. When TBR and TBF locations were visually segregated in two separate frames, and participants explicitly learned the test locations prior to the experiment, an intrusion cost occurred (Experiment 1C and 1D).

Such results could be interpreted as evidence that whether or not a piece of information leaves a trace (thereby triggering an intrusion cost) depends at least partly on the magnitude of its representation in long-term memory. An intrusion cost emerged only if participants had learned the test items prior to the experiment. However, Experiment 1E failed to replicate this effect. In addition, the clarity of the results in Experiment 1D was somewhat compromised by the emergence of an intrusion cost in the accuracy data of the condition using a location set on which participants had not been trained. Given the unpredicted occurrence of an intrusion error in the untrained location set condition in Experiment 1D, and the failure to replicate the intrusion cost altogether in Experiment 1E, the studies reported here provide only partial evidence that no longer relevant material leaves a trace only if participants were familiar with it to begin with.

Does this necessarily imply that the degree to which an item is represented in memory has no influence on the speed with which it decays once it is no longer attended to? Furthermore, are these results evidence that TBF verbal memory representations are processed in a different way than their nonverbal counterparts?

Arguably, in the previous studies, even though participants were able to recall the test items once testing had been completed (suggesting that their long-term memory had retained them throughout participation), one could hardly claim that the representing memory traces had the same strength and resilience as the memory representations corresponding to the words used in Oberauer's study, words that participants encounter and use on a daily basis.

Indeed, it is difficult to manipulate an item experimentally so that in one condition, a participant shall have no pre-existing long-term memory representation of the test stimulus whatsoever, whereas in the other condition, the representation of the same item is of the same strength as an item that we have known for almost all of our life. Experiment 1C and 1D offer some tentative evidence for the role that the extent to which the item is represented in memory plays in our ability to forget it. The training manipulation may have only induced a modest change in the strength with which the no longer relevant material was represented in participants' memory, but this was sufficient to produce a noticeable change in some of the studies reported here, supporting the notion that it is easier to "forget" an unfamiliar item than an item that is firmly established in long-term memory. Nevertheless, it has proven difficult to pinpoint this relationship consistently. In addition, Experiment 1D indicated that training may have had an impact on performance on the basis of altering participants processing strategies, rather than long-term memory formation: Intrusion errors also translated to configurations that participants had not learned.

If intrusion errors and intrusion costs are associated with familiarity, results in Experiment 1D may suggest that there are other ways to stimulate feelings of familiarity than the resilient activation of matching memory traces. A plausible interpretation is that when stimuli are not represented in long-term memory, the crucial type of familiarity underlying the intrusion cost may be triggered by processes that are unrelated to long-term memory support. As already indicated in the introduction of this thesis, one alternative interpretation of familiarity is that the repeated presentation of the item may lead to a facilitation of the processing of this item. Such facilitation in perceptual fluency, rather than the detection of a long-term memory representation that matches the properties of the item, may be the trigger of the type of familiarity (Whittlesea, 1993) that drives the intrusion cost. This possibility is discussed in more detail in the following chapter.

(3) SERIES 2: WHAT KIND OF FAMILIARITY PRODUCES THE INTRUSION COST?

To recapitulate, Oberauer's argued that TBF items are not rejected as quickly as control items because their previous occurrence triggers a familiarity signal that needs to be overwritten by conscious recollection processes, in order to arrive at the correct decision that this item was not to-be-remembered. In contrast, control probes are rejected quickly because they had not been seen before and therefore do not trigger such familiarity signal. Thus, Oberauer's interpretation of the intrusion cost relied on the assumption that recognition memory is made up of two processes – familiarity and recollection (e.g. Mandler, 1980; Yonelinas, 1999). According to Oberauer (2001), feelings of familiarity occur when a memory representation corresponding to the stimulus is still activated. Recognition involves the conscious retrieval of the context in which the item had been encountered (evidence for this dual-process model of recognition has been reviewed above).

However, the view that familiarity relies on the detection of an activated long-term memory trace that matches the stimulus (Yonelinas, 2002) is not unequivocally shared by all researchers in the recognition domain. Alternative interpretations have been developed suggesting that the experience of recognising an item as "old" may not necessarily require stable long-term memory traces, but could also be attributed to an enhanced perceptual processing due to the repeated presentation of the item.

For example, the mismatch theory (Johnston & Hawley, 1994) argues that detailed processing of well-known stimuli would waste limited capacity that could be invested in the processing of novel stimuli instead. When a stimulus matches a representation in memory, initial bottom-up processing occurs with an "ease" that causes feelings of familiarity. This then leads to the use of non-analytic, top-down processing.

A considerable body of research in support of the notion that familiarity is created by processing ease was provided by Whittlesea and colleagues. For example, Whittlesea, Jacoby & Girard (1990) demonstrated how such use of processing fluency can sometimes even lead to familiarity illusions in the absence of the prior occurrence of an item. In a recognition test asking participants to identify learned words from a set of old and novel words, Whittlesea et al. manipulated perceptual fluency of a target by masking it with varying densities of visual noise. They found that participants were especially susceptible to false alarms if the novel item was easier to process visually due to little visual noise. From this it was concluded that participants incorrectly interpreted fluent perceptual processing as an indication of familiarity.

Similar findings were obtained by manipulating the ease with which an item can be processed conceptually, suggesting that this phenomenon is not confined to perceptual fluency alone. Jacoby and Whitehouse (1989) found that in a recognition test, the probability of committing false alarms increased with nontargets that shared the same context as the studied stimuli. Presumably, such words are easier to process than nontargets that are unrelated to the learned items, and it is this processing ease that may have prompted participants to identify the item as old. Similar results were obtained by Whittlesea (1993), who presented new and previously studied items as part of a sentence. Some sentences were more predictive of the target word than others. Participants were more likely to identify novel words as seen before if they were presented in a predictive than nonpredictive context, again suggesting that greater fluency of processing created a feeling of familiarity.

Whittlesea and Williams (1998) reported that perceptual fluency on its own may not be sufficient to create feelings of familiarity. In their study, participants identified old and novel words from three categories: natural words (e.g. "FROG"), pseudohomophones ("PHRAWG") or nonwords (e.g. "LAFER"). Participants needed to pronounce the word prior to making a recognition judgement. Most false alarms were created with novel pseudohomophones, rather than natural words. This was interpreted as evidence that feelings of familiarity are produced by a mismatch between expected and actual processing fluency. When presented with a pseudohomophone, lack of prior experience with this item prompted participants to assume that they would not be able to process this item easily. This expectation was then violated as participants pronounced the word: Because the word matched the phonological representation of a real word in memory, it was actually quite easy to pronounce. According to the authors, it was this discrepancy between expected and actual perceptual fluency that created an illusion of memory. Lloyd, Westerman and Miller (2003) osberved that - at least in verbal memory – processing fluency was quite robust and affected recognition memory even 48 hours after initial exposure to the item. They also reported that presenting an item once was quite sufficient to produce processing fluency effects – in fact, at least between-subjects, processing fluency was greater when the initial item was presented once only, rather than five times.

It is important to note that the use of perceptual fluency as an indicator of prior occurrence is not obligatory. Whittlesea (1993) argued that this process is used selectively whenever it is normatively appropriate to expect an influence of past experience on current processing fluency, rather than executing a simple "if fluent, then old" rule. Convergingly, Whittlesea et al. (1990) demonstrated that when participants knew that perceptual fluency was manipulated, they were no longer susceptible to making errors on the basis of false familiarity effects (see also Lloyd et al. (2003) for comparable results). Furthermore, Westerman, Lloyd and Miller (2002) found that processing fluency could only be a successful trigger for familiarity if study and test phase were in the same modality. If, for example, items were presented visually but then tested acoustically, feelings of familiarity were less likely to be created.

In summary, these studies raise the possibility that an intrusion cost can occur purely on the basis of a processing fluency judgement, even in the absence of stable long-term memory traces corresponding to the probe. Perhaps, the training sessions in Series 1 enabled participants to develop strategies for using processing fluency as an indicator of familiarity, whereas those who had not participated in any pre-test training failed to come up with such strategies.

In order to make sense of this hypothesis, a further factor must be taken into account. Studies such as those carried out by Westerman et al. (2002) suggested that perceptual fluency can only create feelings of familiarity if encoding and processing of the stimulus occur in precisely the same manner. A closer examination of the experiments in Series 1, however, revealed that participants may not have been able to employ the same processing strategies at encoding and at test.

To appreciate this problematic issue, it is necessary to consult some of the main findings from previous empirical research about the way in which we process visual information. As already indicated in the introduction, nonverbal stimuli presented within the same visual area are typically encoded in configuration, rather than as separate items (Jiang et al., 2000, De Lillo, 2004). Jiang et al. (2000, experiment 1) conducted a change-detection task in which participants were presented with a fixed configuration of coloured squares. At test, one square was highlighted, and participants needed to judge whether its colour had changed. Jiang et al. (2000) found that participants were quicker to make a correct response if the configuration in which the probe was presented matched the original context in which the square had appeared previously. The same was true if participants had to compare the position of the probe with its original location (Experiment 2). The authors interpreted these findings as evidence that locations are encoded in configuration, rather than as separate entities. Luck and Vogel (1997) found that on average, we are able to hold four of such configurations simultaneously in memory.

Converging evidence was found by De Lillo (2004), who presented participants with nine to-be-remembered spatial locations that were segregated into three clusters. Varying the hierarchical order in which the spatial locations were presented sequentially (see Figure 19, p. 119), De Lillo found that accuracy was higher if the spatial locations were grouped into three clusters (sequence A and B in Figure 19) than if the sequence randomly moved across the three clusters (sequence C).

The clustered presentation of the test items also put a distinct stamp on the response times pattern in sequence A and B: Any time participants initiated the reproduction of a new cluster, response times were elevated at the first item within this cluster (i.e. at item 1, 4, and 7 in the 9 items sequence). No such evidence was found in sequence C, where response times did not follow a clear hierarchical pattern. De Lillo interpreted this as a sign for planning mechanisms initiating the reproduction of the movement pattern within each cluster. Response times at the first position of a cluster were particularly elevated in sequence B, suggesting that because the movement pattern was not predictable from the previous cluster (as was the case in sequence A, where movement patterns were identical in every cluster), each cluster initiation required its own unique planning.[3]

A problematic limitation in De Lillo's study was outlined by Parmentier et al. (2006), who found that the spatial grouping effect disappears when path length is taken into the equation. While performance remained superior with Sequence A (see Figure 19, p. 119) this was not attributed to spatial grouping, but to a change in task execution strategies: Participants may have taken notice of the repeated pattern in each cluster and used this knowledge as a device to reduce memory load.

[3] Similar response times patterns are also typically found in auditory memory (Maybery, Parmentier & Jones, 2002; Parmentier, Maybery & Jones, 2004)

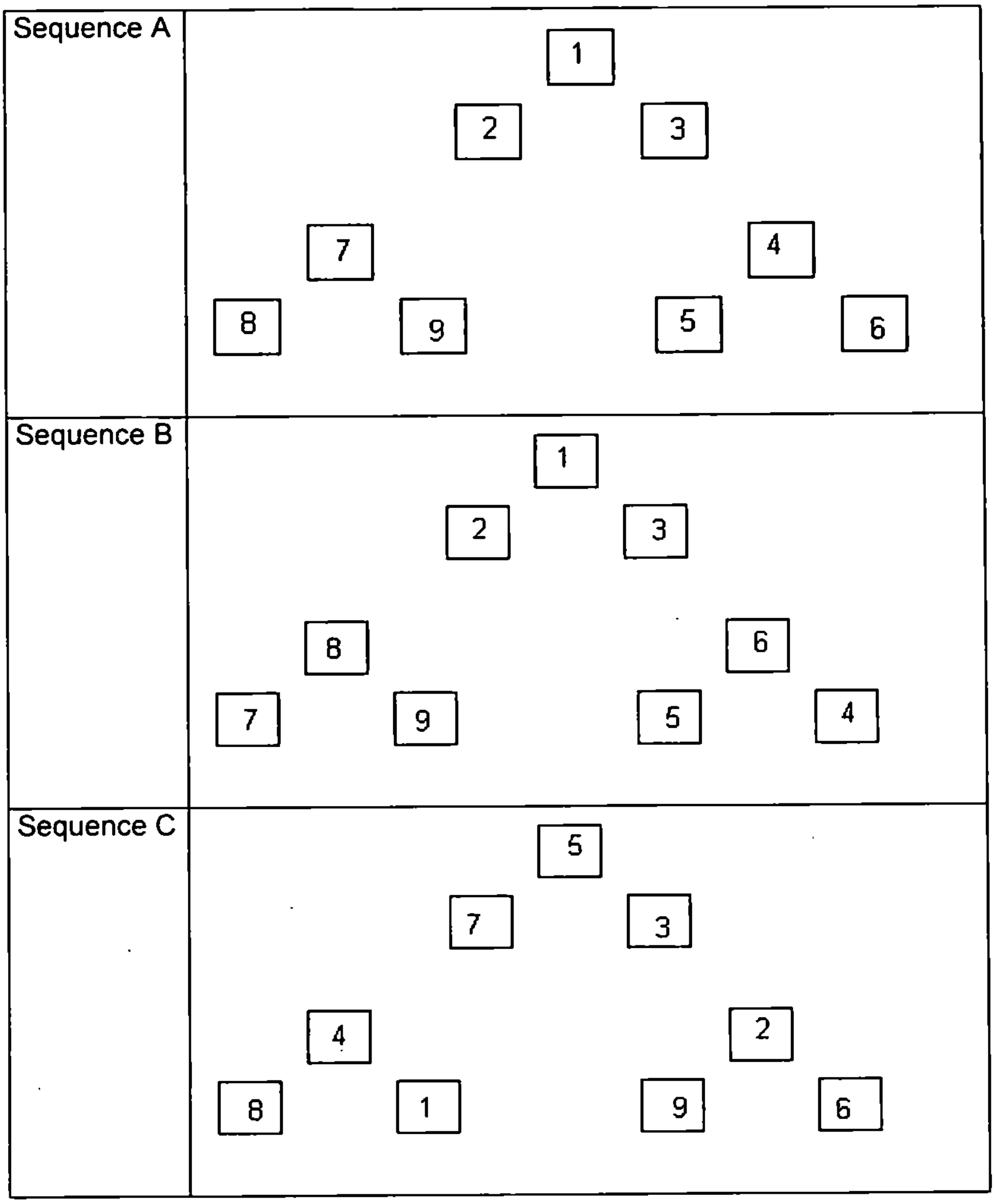

Figure 19: Manipulation of the order in which the spatial locations were presented sequentially in De Lillo (2004), representing various degrees of hierarchical structure. The numbers 1-9 represent the sequential position of the respective square. In A, the sequence moves from one cluster to the next, and movement patterns within each cluster are predictable from the previous cluster. In B, sequences also move from one cluster to the next, but the order is randomised within each cluster. In Sequence C, movements proceed in an unpredictable fashion across all clusters.

Nevertheless, some evidence remains indicating that perceptual organisation may have an impact on spatial memory. Smyth and Scholey (1994a) presented sequences of locations presented in clusters. Varying the spatial proximity between the clusters, they found that performance decreased if the perceptual distance (and thus salience) of the clusters was reduced. Furthermore, Kemps (1999; 2001) suggested that our ability to retain the position of several spatial locations is negatively related to the complexity of the relationship between them. Participants were required to recall sequences of locations on a Corsi blocks matrix. Recall was lower when the path sequence was complex than when it was predictable due to perceptual redundancy (e.g. through symmetrical path patterns, repetition of path sequences, or absence of path crossings). Such results support the notion that comparable to what is found in visual memory studies, sequential locations are not encoded in isolation, but are in relation to one another.

In summary, grouping nonverbal information into one configuration at encoding appears to be a common perceptual strategy to impose structure on incoming stimuli and to condense them into a more economical format.

Linking these findings with the methodology in Series 1, a problem emerges. As outlined earlier, if familiarity is triggered by the facilitation of processing due to the repeated presentation of the item, it is important to ensure that participants are able to resort to the same type of processing when encountering the item again and again (Westerman et al., 2002). Unfortunately, this was not the case in Series 1, where the processes required to analyse the probe were at odds with such encoding strategies:

Participants judged whether a single location (rather than an entire configuration) had been presented as part of the TBR set. Such a presentation presumably requires the mental decomposition of the encoded configuration in order to identify whether the probe was to-be-remembered. Convergingly, one indication that participants were forced to abandon configurational encoding and adopt other strategies was the finding that increasing the TBR set size had a negative impact on performance (Experiment 1E). If participants had treated the TBR and TBF configurations as a whole, they should have processed them as two objects, regardless of the number of locations of which they were made up. As a consequence, no set size effects should have occurred.

It is not clear what strategies participants consulted to solve this kind of task. However, returning to the issue of the underlying effects of the training session, perhaps the reason why an intrusion cost did not emerge in the control condition was that the clash of encoding mode and processing requirements at test made it difficult for participants to use processing fluency as an indication of familiarity. Those who had participated in training, on the other hand, may have simply become more sophisticated with the handling of the stimuli, thereby finding it easier to adopt their processing strategies to the requirements of the task, enabling them to assess familiarity on the basis of processing fluency.

The validity of this theory was tested in experiments presented in Series 2 in which processes required at encoding and at test were made more compatible. This was done to ensure that at test, participants would be able to repeat the same process used at encoding, in order to assess processing fluency for the purposes of estimating the familiarity of the probe.

Crucially, to rule out the assumption that feelings of familiarity are due to the existence of stable long-term memory representations matching the test item (Yonelinas, 1994), participants were no longer required to learn the test items prior to the experiment. If an intrusion cost emerges even in the absence of such memory traces, this might challenge Oberauer's view that long-term memory plays a central role in the creation of the type of familiarity underlying the intrusion cost. An alternative explanation might then be the claim that familiarity is driven by the heightened perceptual fluency with which participants process an item that they had encountered previously (Whittlesea, 1993).

(3.1) Experiment 2A

Experiments in Series 2 investigated whether an assessment of processing fluency (see above for a literature review), rather than resilient long-term memory traces, is required to stimulate the familiarity signal underlying the intrusion cost. Participants again studied two sets of locations followed by a cue indicating the TBR set. Crucially, the probe presentation was altered so that it would be more compatible with processes involved at encoding. Rather than judging a single location, participants were presented with an entire configuration that would either match the TBR set, the TBF set, or would constiute a new configuration. Presumably, this would make it easier for participants to estimate familiarity on the basis of processing fluency, whereby the same type of configurational processing would be employed at encoding and at test. If this is sufficient to trigger familiarity signals, then no long-term memory traces would be required for an intrusion cost to emerge. Thus, no training manipulation was included in the paradigm.

(a) Method

(i) Participants

30 undergraduate students from the University of Plymouth participated in exchange for course credit. Participants had normal or corrected-to-normal vision and did not suffer from colour-blindness. None of them had participated in any of the previous studies.

(ii) Materials

The materials used in this study were identical with those from Experiment 1C, although this time, pre-test training and post-test verification task were not carried out.

(iii) Procedure

This study included a one-way repeated measures design with probe type as the only variable. The procedure was mostly identical to Experiment 1C (see Figure 20, p. 125). Participants studied two configurations highlighted in either blue or orange in a grid of 32 locations, presented in two separate frames. Subsequently, one of the configurations was declared irrelevant. At test - in contrast to previous experiments - participants studied a combination of four locations. This configuration was either identical to the TBR or TBF set, or made up of four locations that had not featured in either set (control probe). Participants judged whether this probe was identical to the TBR configuration, selecting "y" on their keyboard if they thought it was, and "n" if they thought it was not. There were 45 trials in total, 15 for each probe type. The stimuli and probes were fixed within each trial (i.e. every participant saw the same 45 trials), but the order was randomised for each participant, preventing participants from detecting a predictable pattern on the basis of colour allocation in the two frames, cue colour, and probe presentation.

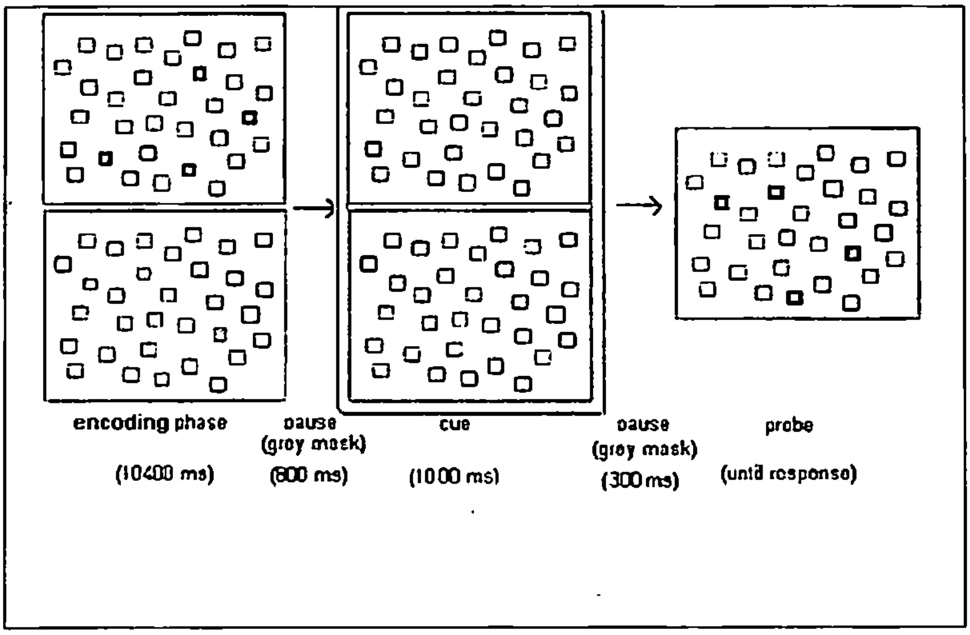

Figure 20: Methodology used in Experiment 2A. In each trial, participants studied two location sets presented in two separate frames in either orange (light-gray squares) or blue (squares shaded in dark-gray). A colour cue around the frame indicated which location set was to-be-remembered. At test, participants judged whether this particular location set corresponded to the TBR location set presented earlier. In this example, a TBR probe is presented. Note that the crucial difference to earlier experiment lay in the presentation of the probe: Whilst previous experiments showed only one location at test, this experiment presented an entire configuration of locations.

(b) Results

(i) Response times analysis

A repeated-measures ANOVA yielded a significant effect of probe type ($F_{1.6, 47.2}$ = 4.8, *MSe* =10530.5, *p* = 0.018). As shown in Figure 21 (p. 126), participants took longer to identify TBR probes (*M* = 894.5 ms, *SD* = 247.8) than control probes (*M* = 828.3 ms, *SD* = 190.1; *p* = 0.022) or TBF probes (*M* = 832.8, *SD* = 188.3; *p* = 0.023), but there was virtually no difference between the latter two probes (*p* = 0.8).

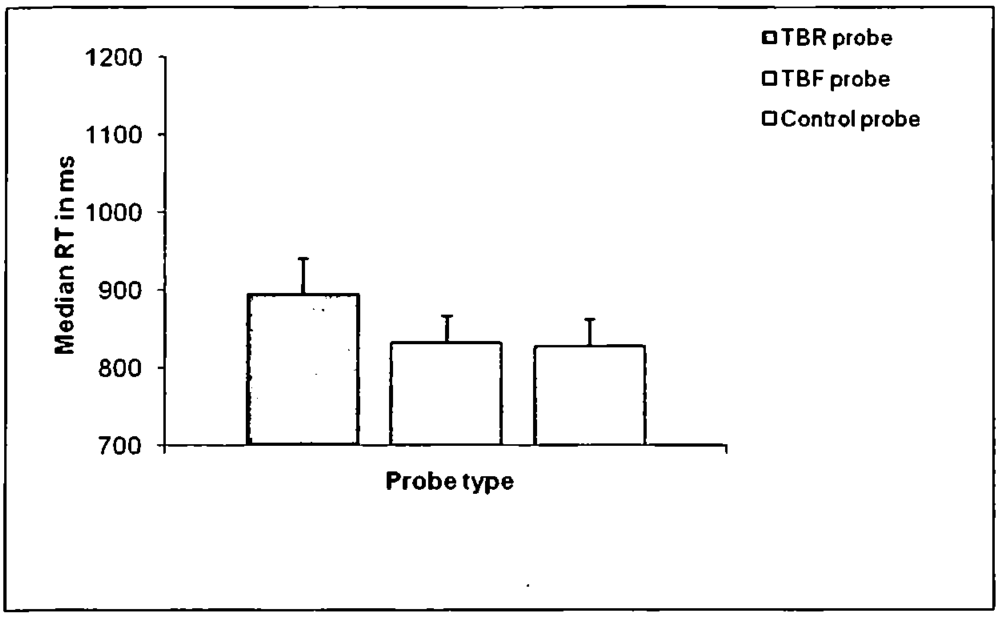

Figure 21: Median response times data in Experiment 2A (error bars represent 1 standard error of the mean). No intrusion cost was observed – response times were virtually identical between TBF and control probes.

(ii) Accuracy analysis

A significant main effect of probe type was also found in the accuracy data ($F_{2,58}$ = 3.5, *MSe* = 65.3, *p* = 0.035, see Figure 22, p. 127). Numerically, participants performed slightly worse with TBR (*M* = 89.8%, *SD* = 9.8) than control probes (*M* = 93.8%, *SD* = 6.8; p = 0.076), but there was no accuracy difference between TBR and TBF probes (*M* = 88.5%, *SD* = 8.0; *p* = 0.575). Participants were reliably more accurate with control probes than TBF probes (*p* = 0.003).

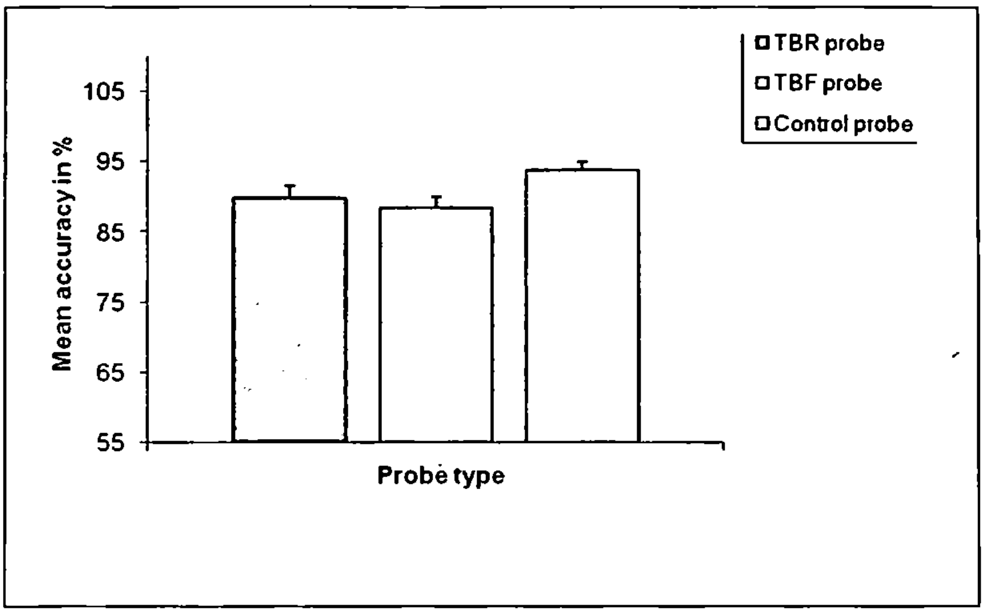

Figure 22: Mean accuracy (error bars representing 1 standard error) in Experiment 2A. Significant intrusion errors were observed, whereby participants rejected control probes more accurately than TBF probes.

(c) Discussion

Results provided some indication that the kind of familiarity required for triggering an intrusion cost does not necessarily rely on the presence of resilient long-term memory traces corresponding to the TBF material. While there was no intrusion cost in the response times data, participants did commit statistically significant intrusion errors. Thus, even though they had not encountered or memorised the test stimuli prior to the experiment, thereby not having strong long-term memory representations of this material, the TBF probes still triggered a familiarity signal that was strong enough for an intrusion error to emerge.

In comparison to previous experiments, both accuracy and response times improved quite substantially in this study, in particular in response to TBR probes.

Presenting the probe as a configuration thus appeared to suit participants' processing style much better than a single location probe.

Such results are somewhat comparable to what was found with verbal material in Oberauer's directed forgetting study (2001). Oberauer observed longer response times with TBF than control probes, interpreting this as evidence that TBF memory traces remain activated in memory, thereby triggering a familiarity signal that needs to be overwritten by recollection in order to accurately reject it as not to-be-remembered. In Oberauer's model, only TBR material resides in the direct access region, while no longer attended material is transferred to the activated subset of long-term memory where its activation decays only gradually.

The present study provided evidence to indicate that such long-term memory activation may actually not be a prerequisite for an intrusion cost. Because participants had not encountered the test items used in Experiment 2A, it is unlikely that they had any pre-existing representations in long-term memory corresponding to the test items. Nevertheless, intrusion errors emerged all the same. Attributing familiarity to an assessment of processing fluency, rather than long-term memory activation can account for such an outcome.

Of course, in order to be entirely comparable to Oberauer's findings, it would be necessary to observe an intrusion cost (i.e. longer response times to TBF probes in comparison to control probes), rather than intrusion errors. Furthermore, the rather unreliable reoccurrence of intrusions in Series 1 demonstrates the important need to replicate the intrusion effect before definite conclusions about its nature can be drawn. Experiment 2B was designed to do just that. In addition, the background grid was removed from the frames in order to increase the salience of the tested configurations. The grid had originally been introduced to provide a frame of reference for participants that would increase accuracy in the single location probe studies, and to enable participants to learn the location set from which test items would be drawn. None of these points bear relevance to the present paradigm where accuracy was much better than previously, and where participants did not learn the test locations prior to the experiment. Therefore, the following study was a replication of Experiment 2A in which the to-be-learned configurations and probes were presented in otherwise empty frames. It was hoped that maximising the visual salience of the configurations by removing the background grid would enhance the chances of detecting an intrusion cost.

(3.2) Experiment 2B

(a) Method

(i) Participants

49 undergraduate students from the University of Plymouth participated in this study in exchange for course credit. They had not participated in Experiment 2A. With normal or corrected-to-normal eyesight, none of them reported colour blindness. Due to poor accuracy or abnormally long response lags, 3 participants were subsequently dropped from data analysis, leaving a total of 46 participants.

(ii) Materials

The material was identical to Experiment 2A, although this time, participants studied frames that did not contain a background grid. Instead, only the to-be-learned configurations and probes were shown.

(iii) Procedure

As in Experiment 2A, a one-way repeated measures design was used with probe type (TBR probe, TBF probe, control probe) as the only factor. Because the same computer program from Experiment 2A was used, the procedures were identical (see Figure 23, p. 130). In contrast to the previous study, however, I removed the background grid from the trials.

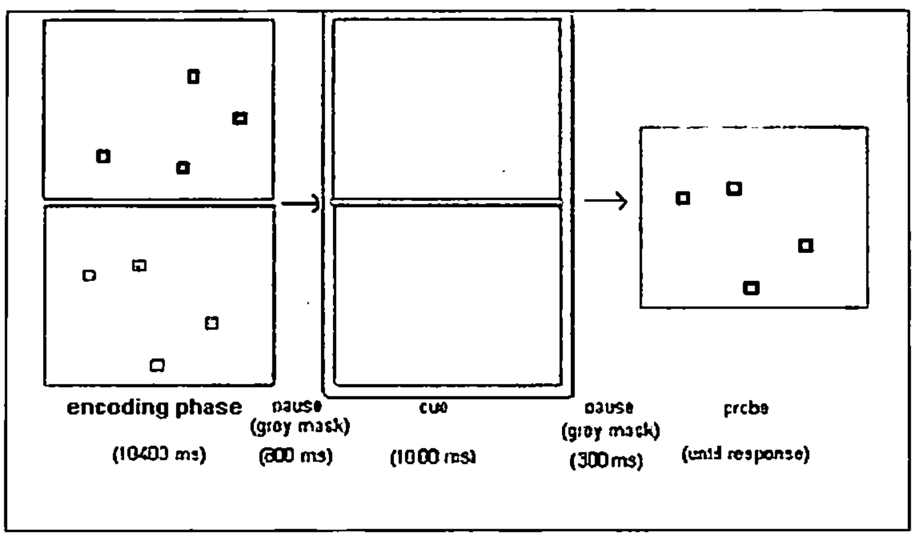

Figure 23: Methodology of Experiment 2B. Participants were again required to learn the two location sets presented in each frame. A colour cue around the frame indicated which set was to-be-rememberd. At test, a location configuration was presented, requiring participants to judge whether this configuration matched the TBR location set. In this example, a TBR probe is shown.

(b) Results

(i) Response times analysis

For median response times, there was a significant main effect of probe type ($F_{2, 90}$ = 4.3, *MSe* = 7822.6, p = 0.016, see Figure 24, p. 131). Participants were reliably faster with TBR than TBF probes (p = 0.026). There was no significant difference between TBR and control probes (p = 0.479). Importantly, there was evidence for the emergence of an intrusion cost: TBF probes were rejected more slowly than control probes (p = 0.008).

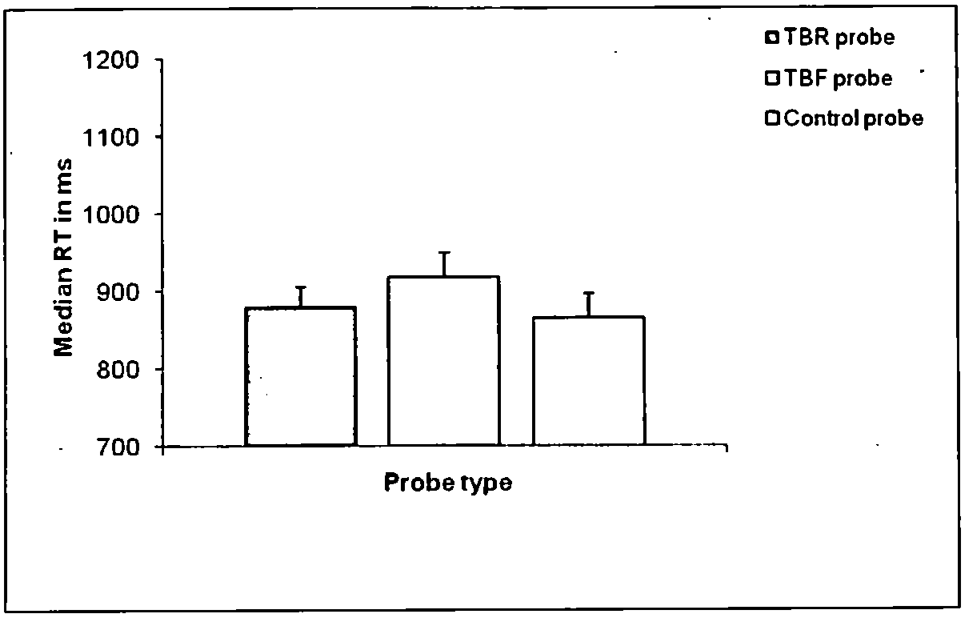

Figure 24: Median response times in Experiment 2B. Error bars represent one standard error of the mean. The graph demonstrates evidence for an intrusion cost, whereby participants took longer to reject TBF than control probes.

(ii) Accuracy analysis

Accuracy was near ceiling for all three probe types, with no significant main effect ($F_{1.7, 76.5}$ = 0.939, MSe = 68.3, p = 0.382) and no observable differences between them (see Figure 25, p. 132).

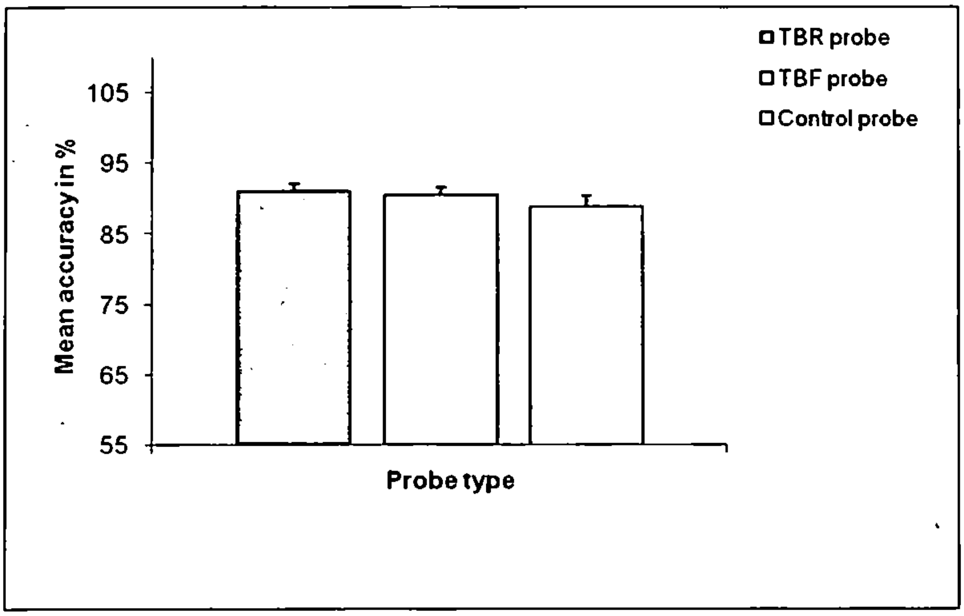

Figure 25: Accuracy in Experiment 2B, with error bars representing one standard error of the mean. As is quite apparent in this graph, performances were near ceiling in response to all three probe types, and no reliable intrusion errors were found.

(c) Discussion

In this study, attempts were made to maximise the salience of the test configurations by removing the potentially distracting background grid. In doing so, response times were very similar to those found in Oberauer's verbal memory study (2001): Participants were just as quick with TBR probes as control probes. Importantly, their response times were significantly longer when presented with a TBF, rather than TBR or control probe. Thus, an intrusion cost was observed without the need for stable long-term memory traces slowing down the decay of no longer relevant material. In the present study, the absence of any unused locations on the screen (which could have acted as a distraction in the previous experiment) made the task easy enough for participants' accuracy to reach near-ceiling levels in response to all three probe types. As a consequence, it was not possible to detect any accuracy differences in this experiment.

Comparing this data with previous single location probe experiments may include one potential caveat : Because this study used a much larger sample, one may argue that perhaps, if more participants had been used previously, similar results could have been observed. There are a number of reasons why I consider this to be unlikely. The results were monitored continuously as new participants were added to this study, and an intrusion cost emerged very early on with as little as 15 participants. Furthermore, consistent with all other configurational probe studies in Series 2 (see above and below), performance had less variance and a much smaller range across the three probe types. Accuracy and response times were also much better in comparison to studies with single location probes. Importantly (with the obvious exception of those studies where an intrusion cost or error was reported), results in Experiment 1A, 1B and 1E (those experiments lacking evidence for an intrusion cost) pointed in the opposite direction to what would be predicted for an intrusion cost, making it unlikely that low statistical power is an explanation for the results. All this suggests that there were real performance discrepancies between the two paradigms.

Thus, even though an intrusion cost failed to emerge with single location probes unless participants had learned the test items prior to the experiment, no training was required for the occurrence of an intrusion cost if the probe was presented as a configuration.

Assuming it was unlikely that participants had stable long-term memory traces of the spatial test items, this was once again in line with the notion that the emergence of familiarity (and by association an intrusion cost) does not necessarily require activated long-term memory traces. Instead, the simple repeated processing of a TBF stimulus may be sufficient to create a feeling of familiarity that participants must overwrite through conscious recollection in order to make the correct decision that this item was not to-be-remembered.

(3.3) Experiment 2C

One way of providing further evidence for the notion that processing fluency, rather than long-term memory activation drives the intrusion cost with the type of material used in this study would be to examine whether the magnitude of the intrusion cost is negatively related to an increase in the delay between cue and probe. Oberauer (2001) varied the delay between cue and probe in six steps (100 ms, 300 ms, 600 ms, 1000 ms, 2500 ms and 5000 ms) and found intrusion costs with all durations. The size of the cost, however, decreased steadily between 100 ms and 1000 ms (remaining stable thereafter). This occurred through a drop in response lags with TBF probes - response times to control probes remained unaffected by the duration of the delay. Oberauer interpreted this as evidence that the activation of the memory traces of the TBF material had started to decay, making the intrusion cost increasingly smaller in size. Participants' memory of TBR items were also relatively unaffected by the duration delay manipulation, suggesting that they were actively maintained in the direct access region, while only those items in the activated subset (TBF items) were subject to decay.

If in the previous two experiments familiarity was somehow achieved by the residual activation of slowly decaying memory representations, similar effects of cue-probe lag interval should be observed here. Oberauer argued that the intrusion cost diminished over time, because increasing the cue-probe lag only affected memory of the TBF material, leading to a gradual decay (TBR material presumably continued to be rehearsed during the interval and remained therefore unaffected).

If, on the other hand, processing fluency was the underlying trigger of the familiarity signal that induces the intrusion cost, a different prediction could be made. The perseverance of the processing fluency effect over time has been found to be quite robust: Lloyd et al. (2003) found evidence for processing fluency biases up to 48 hours after the initial presentation of the word. It is possible that, provided the configuration has been presented repeatedly, processing fluency is equally robust in nonverbal memory: Research by Chun and Jiang (2003) indicated that in a target-detection task in a spatial matrix, repeatedly presenting the same spatial context boosted participants' performance even with a delay of up to a week.

However, it is important to bear in mind that the results by Lloyd et al. (2003) were based on an experiment with verbal stimuli – items that are well represented in long-term memory, and that participants process regularly in everyday life. Furthermore, Chun and Jiang (2003) used a very different task to what was used here: They only found evidence for processing priming in an implicit memory task (measuring participants' speed in identifying a target in a repeated configurational matrix). When participants were asked to explicitly identify the repeated configurations, they were unable to do so. This suggests that perhaps it is harder to detect processing fluency effects in an explicit nonverbal memory task. Importantly, Chun and Jiang's study indicated that processing priming in nonverbal memory is not a rapidly developing effect: In Experiment 1, for example, clear performance benefits did not emerge until the fourth repetition of the configuration, demonstrating that nonverbal items must be presented repeatedly before processing priming can occur.

In this study, participants studied pairs of novel spatial configurations only once before being presented with the probe. This distinguishes the experiment from the studies reported above, making firm predictions more difficult. Presumably, however, with novel items that were only presented once, processing fluency should be less robust over time and therefore more susceptible to decay. If this is the case, then an extension of the delay between cue and probe would result in a decaying familiarity signal for both TBR and TBF probes. In other words, with longer delays, participants should find it increasingly more difficult to rely on feelings of familiarity in order to decide whether the probe was old or not. Longer delays should then lead to longer response delays and lower accuracy in response to all three probe types, since participants would find it increasingly more difficult to distinguish between new and old items based on familiarity ratings. Comparable to Oberauer's findings, intrusion costs should decrease with longer delays – however, in this case, this would not be due to an isolated change in response times to TBF items, but instead to a more general effect on all three probe types.

Experiment 2C tested these hypotheses. Using the same general paradigm administered in Experiment 2B, the cue-probe interval was varied systematically in four steps. To measure whether this had an effect on the intrusion cost, particular attention was paid to a comparison of responses to TBF and control probes in each delay condition.

(a) Method

(i) Participants

37 undergraduate students from the University of Plymouth participated in exchange for course credit. They reported normal or corrected-to-normal eyesight, and none of them suffered from colour blindness. Due to poor accuracy, 3 participants were subsequently excluded from the analysis.

(ii) Materials

The materials were the same as used in Experiment 2B. The to-be-learned and probe configurations were again presented without a background grid.

(iii) Procedures

In this study, a 3 (probe type: TBR, TBF, control probe) x 4 (delay: 650 ms, 1300 ms, 2600 ms, 5200 ms) repeated measures design was used. The main procedures were identical as in Experiment 2B. In addition, the experiment included a systematic variation of the delay between cue onset and probe presentation (650 ms, 1300 ms, 2600 ms, 5200 ms). 45 trials (15 per probe type) were compiled for each duration, amounting to a total of 180 trials. The different delays were presented in blocks (presented In randomised order across participants), to allow participants to get used to the duration, thereby avoiding any performance disruption caused by ever-changing cue-probe durations. Within each block, trials were randomised to prevent predictable patterns in colour cue and probe type order.

(b) Results

Results were analysed using a repeated-measures ANOVA with delay and probe type as factors. Due to the complexity of the data, only the most relevant results are mentioned here. For further output, please consult Appendices.

(i) Response times analysis

For response times, there was a reliable main effect of probe type ($F_{1.6,53.7}$ = 6.4, *MSe* = 14043.3, p = 0.006). LSD comparisons showed that overall, participants responded faster to control probes (*M* = 778.5 ms, *SD* = 221.8) than TBR probes (*M* = 823.4 ms, *SD* = 224.9; p = 0.004) and TBF probes (*M* = 810.6, *SD* = 243.3; p = 0.002). No significant differences emerged between TBR and TBF probes (p = 0.372).

Effects of delay. The main effect for delay was highly significant ($F_{3,\ 99}$ = 9.7, *MSe* = 28678.1, p < 0.001). LSD tests suggested that response times were longer with delays of 5200 ms (*M* = 865.7 ms, *SD* = 260.1) than 650 ms (*M* = 791.2 ms, *SD* = 198.4; p = 0.011) and 1300 ms (*M* = 741.1 ms, *SD* = 212.0; p < 0.001), although the difference to 2600 ms just missed significance (*M* = 818.5 ms, *SD* = 232.0; p = 0.06). Response times were fastest in the 1300 delay block, and this was significant in comparison to 650 ms (p = 0.026), 2600 ms (p < 0.001) and 5200 ms (p < 0.001). There was no significant interaction between probe type and delay ($F_{4.3,142.5}$ = 0.5, *MSe* = 10112.5, p = 0.757), suggesting that performance patterns were similar in each delay condition (see Figure 26, p. 140).

Intrusion cost analysis. Even though no significant interaction between probe type and delay was found (see above), post hoc tests were carried out all the same to assess whether an intrusion cost could be detected in any of the delay conditions.

LSD tests indicated that although response times were consistently longer with TBF relative to control probes, reliable intrusion costs were only observed in the 650 ms delay block (p = 0.025; main effect of probe type: $F_{2, 66}$ = 3.8, MSe = 6513.4, p = 0.027) and 2600 ms delay block (p = 0.004; main effect of probe type: $F_{2, 66}$ = 5.1, MSe = 8000.6, p = 0.009). Response times were comparable between TBF and control probes in the 1300 ms delay block (p = 0.185; main effect of probe type: $F_{2, 66}$ = 2.1, MSe = 6452.1, p = 0.137) and 5200 delay block (p = 0.582, main effect of probe type: $F_{1.6, 53.4}$ = 0.4, MSe = 15196.6, p = 0.649). A finding that will be discussed later is that the intrusion cost disappeared in the 5200 delay period because response times became significantly longer with control probes (p = 0.046; main effect of delay for control probes: $F_{2.4, 77.8}$ = 6.2, MSe = 21704.4, p = 0.002). With TBF probes, there were no performance differences between 2600 ms and 5200 (p = 0.216; main effect of delay for TBF probes: $F_{13, 99}$ = 6.0, MSe = 15361.8, p = 0.001).

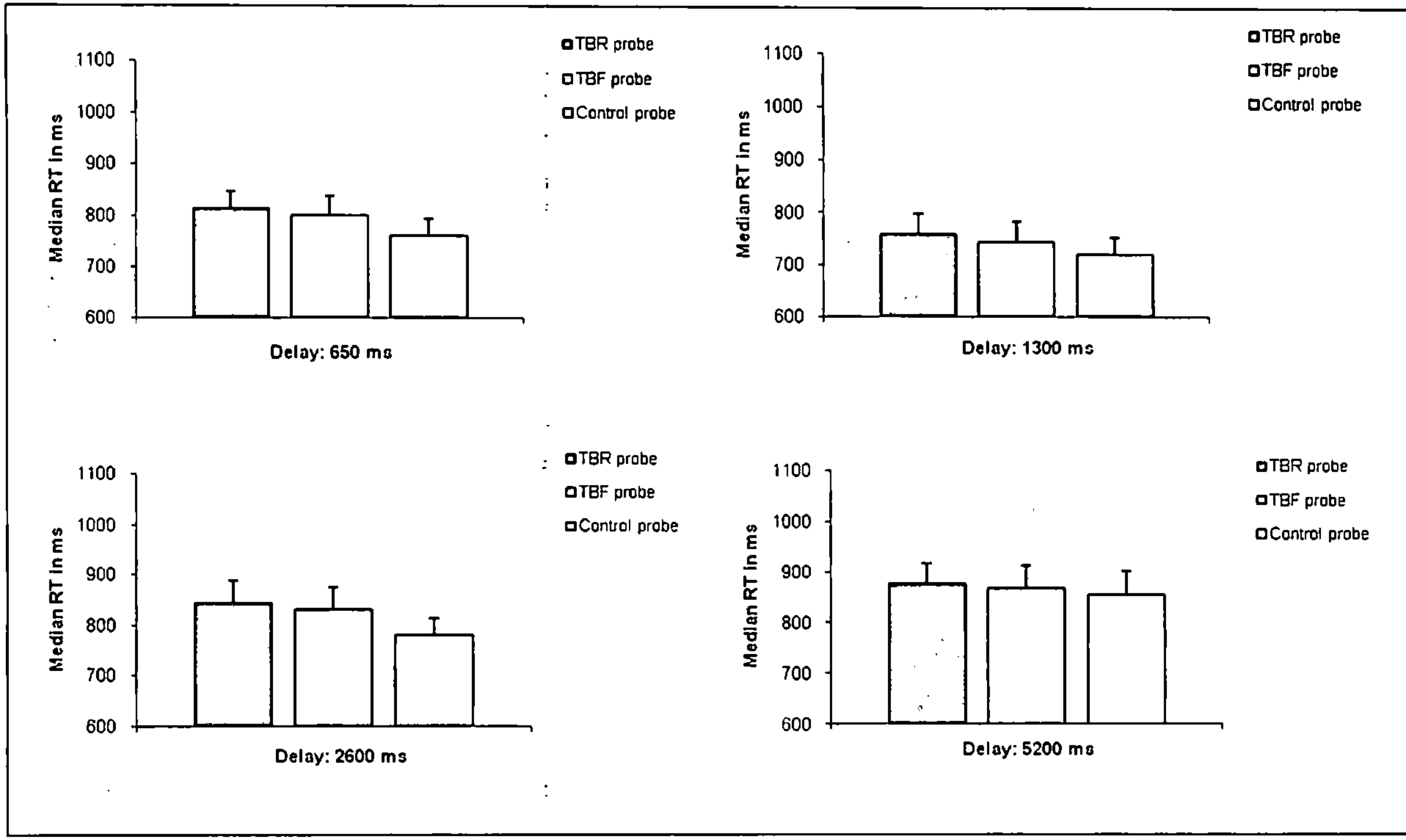

Figure 26: Median response times data (including error bars representing one standard error of the mean) in Experiment 2C. Overall, increasing the delay between cue and test slowed down response times, although this trend did not surface between 650 ms and 1300 ms. An intrusion cost was observed with delays of 650 ms and 2600 ms.

(ii) Accuracy analysis

Across delay conditions, accuracy yielded a significant main effect of probe type ($F_{2,66}$ = 5.9, *MSe* = 141.9, p = 0.005). Performance was highest in response to control probes (*M* = 93.0%, *SD* = 10.2), although this was only significant in comparison to TBR probes (*M* = 88.1%, *SD* = 11.1; p = 0.003). Participants also performed significantly better with TBF probes (*M* = 91.2%; *SD* = 8.9) than TBR probes (p = 0.033).

Effects of delay. The main effect of delay was significant ($F_{3, 99}$ = 7.0, *MSe* = 68.9, p < 0.001), although this was mainly due to large discrepancies between the 5200 ms delay block and the rest of the delay conditions. Performance was high overall, and virtually identical in the 650 ms (*M* = 91.6%, *SD* = 9.8), 1300 ms (*M* = 92.9%, *SD* = 8.8) and 2600 ms (*M* = 91.0%, *SD* = 10.7) block. Participants were significantly worse with delays of 5200 ms (*M* = 87.7%, *SD* = 11.1) than 650 ms (p = 0.003), 1300 ms (p < 0.001), and 2600 ms (p = 0.013). A significant interaction between probe type and delay ($F_{4.3, 140.6}$ = 2.5, *MSe* = 79.5, p = 0.043) suggested that across delays, performance patterns varied between the three probe types (see Figure 27, p. 142, and Appendices).

Intrusion error analysis. Significant intrusion errors were found only in the 650 ms delay condition (p = 0.005; main effect of probe type: $F_{2, 66}$ = 8.5, *MSe* = 63.1, p = 0.001). None of the other delay conditions yielded intrusion errors.

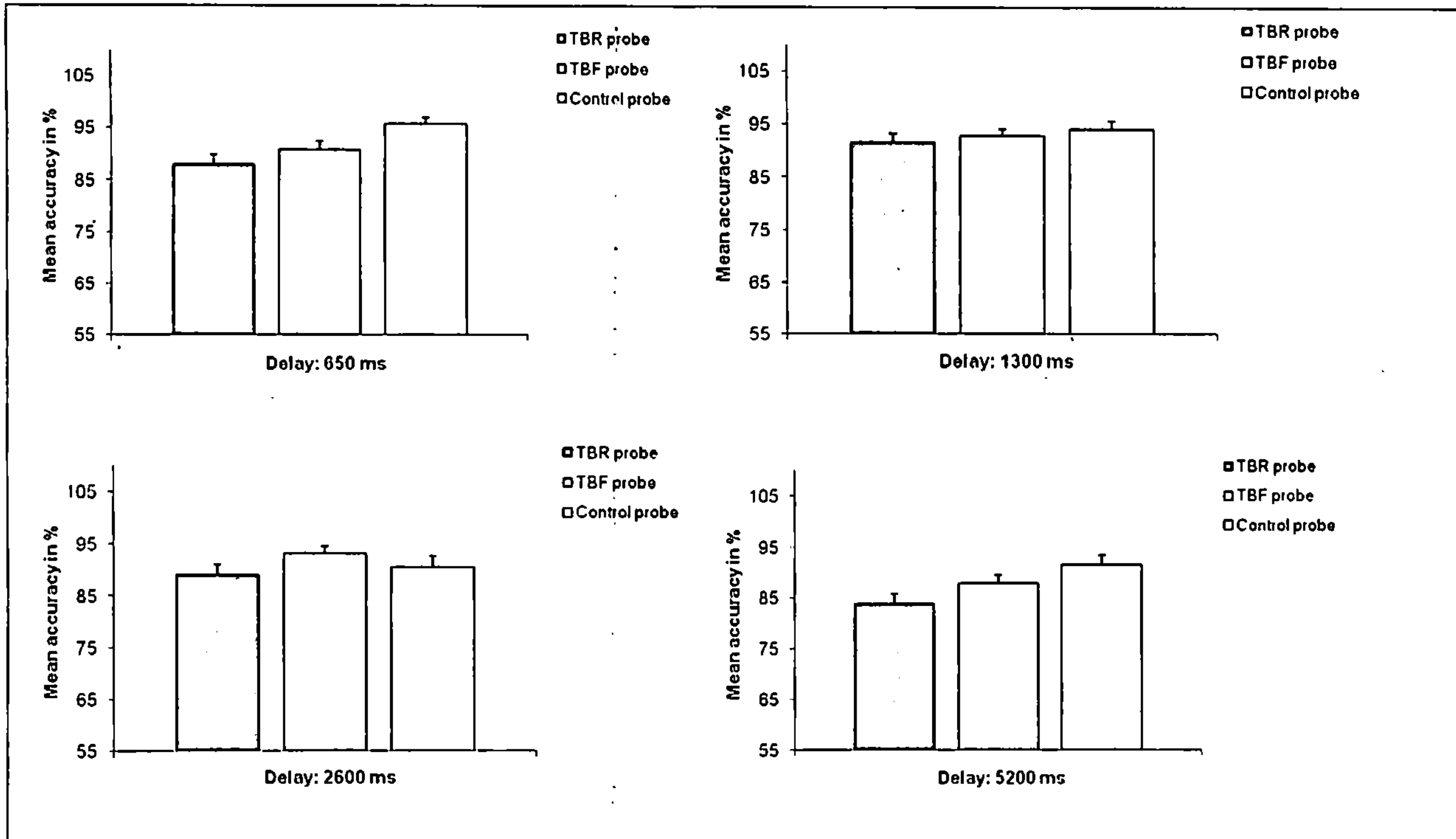

Figure 27: Mean accuracy (error bars reflecting 1 standard error of the mean) in Expriment 2C. Overall, performance was comparable for delays up to 2600 ms. Accuracy dropped significantly in the 5200 ms delay condition in comparison to all shorter delays (but was still relatively high). An intrusion error was only found with a 650 ms delay.

(c) Discussion

In line with Experiments 2A and 2B, an intrusion cost was replicated in the 650 ms and 2600 ms delay conditions. With delays of 650 ms, an intrusion error was also observed. This provided corroborating evidence that intrusions can emerge even in the absence of long-term memory representations.

Oberauer (2001) found that response times increased only with TBF probes. Indeed, if stimulus familiarity in this study had been driven by residual long-term memory activation, then only the TBF probes should have been affected by increasing the delay between cue and probe. This is because memory for TBR items would have been actively maintained in the direct access region, with only the TBF memory traces gradually decaying. Since there are no memory traces for the control probes, they should also remain unaffected by varying the cue-probe interval.

Results demonstrated that with the exception of the 1300 ms block (which will be discussed in more detail below), response times were positively related with cue-probe interval length. An intrusion cost emerged in the shorter delay periods, but not in the longest delay block. In contrast to Oberauer (2001), however, the lack of an interaction between probe type and delay period meant that all three probe types were equally affected by increasing the gap between cue and probe (Figure 26, p. 140, and Figure 27, p. 142, confirm this). Specifically, the response times to TBF probes increased across trials – in Oberauer's study, the opposite pattern emerged. Furthermore, the statistical reason for the disappearance of the intrusion cost in the 5200 ms condition could not be found in any observable changes in response times to TBF probes. Instead, between 2600 ms and 5200 ms, participants only became significantly slower to reject a control probe.

Such results suggested that the underlying processes involved in this study may not be comparable to those that Oberauer observed. They were also in line with a priori predictions from the perspective of a processing fluency account. In previous studies, processing fluency effects were observed 48 hours (Lloyd et al. 2003) and even up to a week (Chun and Jiang, 2003) following the initial presentation of the test item. However, these studies either used items that participants process regularly in their everyday life (Lloyd et al., 2003) or novel items that were presented repeatedly to the participants until a priming effect occurred (Chun and Jiang, 2003).

In this study, participants studied novel configurations that were only presented once to them. It was predicted that this would lead to weaker processing fluency effects (and thus familiarity signals) that were more susceptible to decay. The results support this prediction: As the delay increased between initial processing and reprocessing, the benefits of repeated processing diminished, thereby weakening the familiarity signal of both TBR and TBF configurations. This made it harder for participants to base their judgement on familiarity, thereby lengthening response times to all three probe types.

Nevertheless, these results are not sufficient to completely discard the possibility that the familiarity judgements were based on long-term memory activation. The finding that participants took more time to respond to all three probe types in the longest delay condition may have also been a sign that the memory traces corresponding to both TBR and TBF set had started to fade, thus decreasing the familiarity signal when the configuration was represented at test.

Looking at performance levels in response to TBR probes, however, it seemed perhaps less likely that long-term memory played a considerable role in this study. If participants truly had rehearsed and maintained the TBR configurations in long-term memory, the time taken to respond to a TBR probe should have been unaffected by an increase of cue-probe delay. This was not the case: Together with the two negative probes, response times to TBR probes slowed down as the gap between cue and probe widened.

Thus, in summary, the results were mostly in support with the notion that processing fluency, rather than long-term memory activation, may be the underlying factor involved in the kind of familiarity that drives the intrusion cost. In all experiments of Series 2, there was either evidence of an intrusion cost or intrusion error. This was in spite of the fact that participants had never encountered the items before, and therefore should not have had resilient long-term memory traces strong enough to trigger a reliable familiarity signal. Such a finding is not in line with Oberauer's argument that the intrusion cost is driven by a familiarity signal based on the detection of a strongly activated trace in long-term memory that matches the TBF probe. It does, however, support the idea that perhaps, the underlying mechanism involved in familiarity may be due to the facilitated processing of the TBF probe due to its repeated presentation to the participant (Whittlesea, 1993).

A rather puzzling finding was found in the 1300 ms condition, which would later inspire experiments in Series 3. In this delay condition, performance received a considerable boost, displaying better accuracy and response times than any of the other delay conditions. This finding was particularly unusual considering that the delay was in fact identical with the delays used in my previous studies, and thus should have yielded similar results. In order to understand this outcome, it may help to consider some of the comments that participants tended to make subsequent to most of the studies reported here. Specifically, some explained that with negative probes, they found it easier to make a correct rejection response if the probe was visually clearly segregated from the TBR configuration. By the same token, performance with TBR probes was apparently facilitated if the probe was easily distinguishable from the TBF configuration. Such reports indicated an additional variable that had not been controlled for in previous experiments: The spatial relationship between the test configurations/probes.

Indeed, a closer inspection of the trials in the 1300 ms block showed that the exceptionally fast and accurate performance may have been due to a disproportionate amount of trials in which TBR and TBF set were spatially segregated. To test whether this may be an explanation for what was observed, I randomly looked at the stimuli used in 20 trials in the 1300 ms block and 20 trials in the 650 ms block in order to compare their spatial makeup. In the former, only 4 out of the 20 trials presented TBR and TBF sets within close spatial proximity. In the 650 ms section, on the other hand, there was an even spread of trials with TBR and TBF sets spatially segregated as well as close together (10 each).

Thus, it is a plausible hypothesis to attribute the substantial performance boost observed in the 1300 ms delay condition to peculiarities in the spatial composition of the configurations. The final series of this thesis explored this idea empirically in more detail. Should the spatial proximity between the TBR and TBF configurations prove to have a large effect on response times, then future studies investigating the fate of no longer relevant nonverbal material may need to control for the spatial relationship between the test items. This could potentially be an important factor even in studies where TBR and TBF items were presented in separate frames, because even though it allowed participants to encode the two configurations separately to some extent, the background grid of the two frames was identical and would have still required participants to mentally shift TBR and TBF configurations within the same grid.

(4) SERIES 3: THE SPATIAL INTRUSION COST: A PERCEPTUAL EFFECT?

Series 3 of this thesis explored the hypothesis that the speed with which a no longer relevant spatial location is rejected partially depends on its spatial proximity to a task-relevant location. In previous studies, participants reported that it was easier to reject a probe as not to-be-remembered if it was clearly segregated from the TBR set. Likewise, it was easier to recognise a TBR configuration as old if its spatial position was unambiguously separated from any of the TBF locations. The observation that responses to negative probes appeared to be dependent on their spatial confusability with the TBR set would suggest that there were perceptual, rather than mnemonic aspects that may have shaped the intrusion cost observed in the previous studies.

In the verbal directed forgetting literature, research has found supportive evidence for the intuitive thought that the first step towards selectively ignoring part of what has been stored in memory is the ability to dissociate TBR from TBF material. For example, research by Golding et al. (1994) suggested that when TBR and TBF material become confusable, it is no longer possible to selectively ignore the no longer relevant material (in this case, Golding et al. varied the semantic relationship between the TBF and TBR sets and found that participants showed fewer signs of forgetting if the TBF material was semantically related to the TBR items).

In the memory and perception literature, some evidence exists suggesting that similar effects may occur with nonverbal material. Specifically, the way in which visual information is encoded according to perceptual principles may support the hypothesis that whether or not an "intrusion cost" occurs may in fact not depend on mnemonic factors, but on the perceptual relationship between TBR and TBF material. Two such organisational principles (namely, perceptual grouping and global versus local processing) involved in the encoding of nonverbal information are presented below.

(4.1) Perceptual grouping

While views remain divided on the extent to which attention is involved in grouping[4] (e.g. Kimchi & Rapzurker-Apfeld, 2004), recent research has provided ample evidence for the beneficial effects that temporal or spatial grouping of spatial (e.g. De Lillo, 2004; Jiang et al. 2000), auditory (Parmentier et al., 2004) or verbal (Bowles & Healy, 2003; Cowan, Saults, Elliott & Moreno, 2002; Maybery et al., 2002) information has on memory performance. With regard to nonverbal memory, research suggests that spatial locations are encoded in configuration, and, in an attempt to reduce load on memory, this information is segregated further by grouping locations within close proximity of one another into one chunk. The corresponding literature has already been reviewed above (e.g. Jiang et al., 2000; Kemps, 1999; 2001) and shall thus not be repeated again.

The finding that spatial information is grouped at encoding suggests that the selective rehearsal of the TBR location set is easier if its spatial position does not overlap with the TBF location set. Here, the TBF probe's clear spatial distinction from the TBR set should make it relatively simple to identify it as not to-be-remembered. When TBR and TBF locations are perceptually intertwined, they may be encoded as one configuration, regardless of task-relevance, making it impossible to selectively rehearse one set whilst ignoring the other. Thus, from a perceptual grouping perspective, a clear segregation of TBR and TBF material may lead to speedy

[4] Ben-Av, Sagi and Braun (1992) argue that grouping cannot occur without attention, while research by Driver, Davis, Russell, Turatto and Freeman (2001) suggests that some types of grouping are possible without the deployment of attention. Similarly, it remains unclear whether grouping is a unitary process (as proposed by Han and Humphreys, 1999) or occurs in two stages (Trick & Enns, 1997).

responses (potentially, regardless of probe type), while longer response times are predicted when TBR and TBF materials become spatially confusable.

(4.2) Global versus local processing

In addition to grouping, research has provided evidence for a further important organisational principal of perception. In a study by Navon (1977), participants saw stimuli with both a global and local element (e.g. the letter "H" made up of many "S" letters). In some trials, participants needed to identify the global letter (H), in others, they were instructed to name the local letter (S). Navon also varied the congruity between global and local features and found slower response lags when participants had to name the local letter if it was different from the global letter. In contrast, response times with global letters were unaffected by the congruence of the global and local element. Navon concluded from these findings that perceptual processes gradually decompose a visual stimulus in such a way that they proceed from the global feature towards the processing of more fine-grained local elements. Fagot and Deruelle (1997) found corroborating evidence that performance is typically faster and better with global rather than local features.

Some neuropsychological evidence exists demonstrating that global and local features are processed in separate areas of the brain. Using Navon's selection task (see above), Weissman and Woldorff (2005) carried out an fMRI study demonstrating greater activity for local than global processing in the left hemisphere of the brain. Even though they failed to also provide convincing evidence that the right hemisphere is responsible for global processes, research elsewhere has shown that damage to the right temporo-parietal regions selectively impairs the ability to identify global elements, while damage to the left temporo-parietal regions affects local processing (Robertson, Lamb & Knight, 1988).

In a recent comparative behavioural study, De Lillo, Naylor, Spinozzi and Truppa (2005) presented three objects containing global and local features next to one another. Participants (young children and monkeys) studied the object positioned in the middle of the three stimuli and had to decide which of the remaining two objects was identical with the object in the middle (see Figure 28, p. 151, for an example). Varying the consistency between local and global features, De Lillo et al. demonstrated that visual prioritisation in monkeys is opposite to humans (i.e. monkeys process local features faster than global features, see also Fagot & Deruelle, 1997), and that young children's are equally good at processing global and local levels, suggesting that processing preferences for global features develop over childhood.

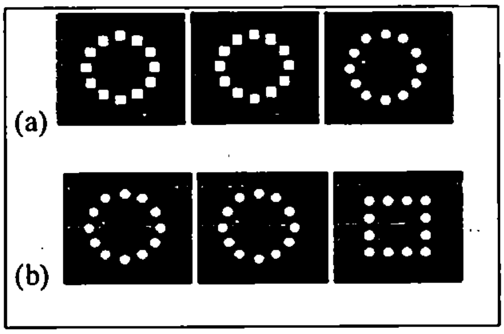

Figure 28: An example of De Lillo et al.'s (2005) stimuli. Participants were required to identify the object that matched the item in the middle (in both examples (a) and (b), the correct answer would be to select the left object). In Example (a) the critical item contains a mismatch between local (squares) and global features (circle), while in example (b), the critical item has local and global features that are complementary (both are circles). De Lillo et al. measured response times and accuracy to objects with matching and nonmatching local and global features and found that monkeys' performance deteriorated if they were required to attend to the global feature of the object. Children's performance remained unaffected by matching or nonmatching features, suggesting that they are equally good at processing an object on a global or local level.

It is possible to apply this theoretical framework to this thesis: Robertson (1996) argued that most visual scenes are perceived according to hierarchical principles in which larger sized global shapes are made up of smaller, local shapes. Indeed, such a hierarchical structure also existed in the stimuli used in the experiments reported here: TBR and TBF location sets could be perceived on both a global level (the complete configuration) and a local level (a single location). Thus, in those studies presenting the probe as a single location (Series 1), participants might have alternated their processing strategies depending on the scenario they were faced with: Whenever the negative probe was clearly distinct from any of the TBR items, global processing recognising that the probe was nowhere near any of the TBR locations may have been sufficient to reject this probe as not to-be-remembered. Slower, more elaborate local processing may have been required whenever the negative probe was spatially confusable with a neighbouring TBR item to ascertain that no TBR location had occupied this position.

In contrast, when the probes were presented as a configuration (Series 2), no local processing would have been required. Research has established that for economical reasons, spatial configurations are typically encoded and processed as a whole, or, in other words, on a global processing level (Jiang et al., 2000). If both stimulus and probe are presented as an entire configuration, participants would therefore only require global processing, rather than having to process each individual location that was included in the configuration. With such global processing, response times should not be as easily modulated by the spatial relationship between the negative probes and the TBR set. Indeed, Experiments 2A-2C demonstrated that performance variances between the three probe types were much smaller than those found in Series 1. This demonstrates that when the test environment allows participants to employ global processing strategies, the influence of the spatial distinction between TBR set and negative probes diminishes.

Furthermore, with TBR probes in Series 1, participants presumably always needed to engage in local processing mechanisms to verify that this probe occupied the exact location of a TBR item studied earlier. Consequently, performance with TBR probes should always remain poorer in comparison to the two negative probes. Indeed, this was the typical finding in the studies of Series 1. By comparison, in Series 2 (where entire configurations were presented as probe), there were only small response times and accuracy differences between the TBR and negative probes. From a global/local processing perspective, this could indicate that because the probe was presented as a configuration, participants were able to resort to the same type of fast, global processing regardless of probe type.

In summary, response times in Series 1 and 2 may have been the reflection of differential processing strategies depending on the perceptual relationship between the TBR set and negative probes. In other words, theories arguing for the existence of perceptual grouping mechanisms and local/global processes provide a theoretical foundation for the assumption that the "intrusion cost" may have been the result of perceptual, rather than mnemonic factors. At this point, it is important to note that the two approaches discussed above are not viewed as competing accounts for the interpretation of the results in Series 1 and 2. Rather, they are treated as complimentary explanations for the processes in which participants may have engaged.

Experiments in Series 3 explored the extent to which the perceptual organisation of TBR and TBF material has an impact on performance. Experiment 3A investigated the impact of spatial proximity between TBR and TBF sets using a single location probe. Findings were analysed bearing those in mind that were presented in Series 1. Experiment 3B examined spatial proximity effects with configurational probes, comparing results with those from Series 2.

In accordance with what was discussed above, in Experiment 3A (single location probe) it was predicted that responses would slow down whenever the position of a TBF or control probe was spatially confusable with a TBR location, because participants would need to engage in local processing to verify that this was not a TBR probe. In contrast, fast responses were predicted in trials where the negative probe was clearly spatially segregated from the TBR set. Performance with TBR probes should remain unaffected by spatial proximity manipulations, because presumably, participants would always need to engage in local processing strategies verifying that this precise location matched a TBR item.

Different results were predicted for Experiment 3B, where the probe was presented as an entire configuration. While results from the 1300 ms condition in Experiment 2C gave some preliminary indication that the spatial relationship between TBR and TBF configurations may have an impact on performance even when configurational probes are used, it was nevertheless anticipated that spatial proximity would have a smaller effect in Experiment 3B. This prediction was based on the assumption that presenting an entire configuration as probe should enable participants to always rely on the same global, configurational processes, regardless of probe type or the spatial relationship between the TBR and TBF set.

(4.3) Experiment 3A

In this study, the methodology was similar to that used in experiments in Series 1. A new matrix was created to manipulate the spatial proximity of the TBR and TBF location set.

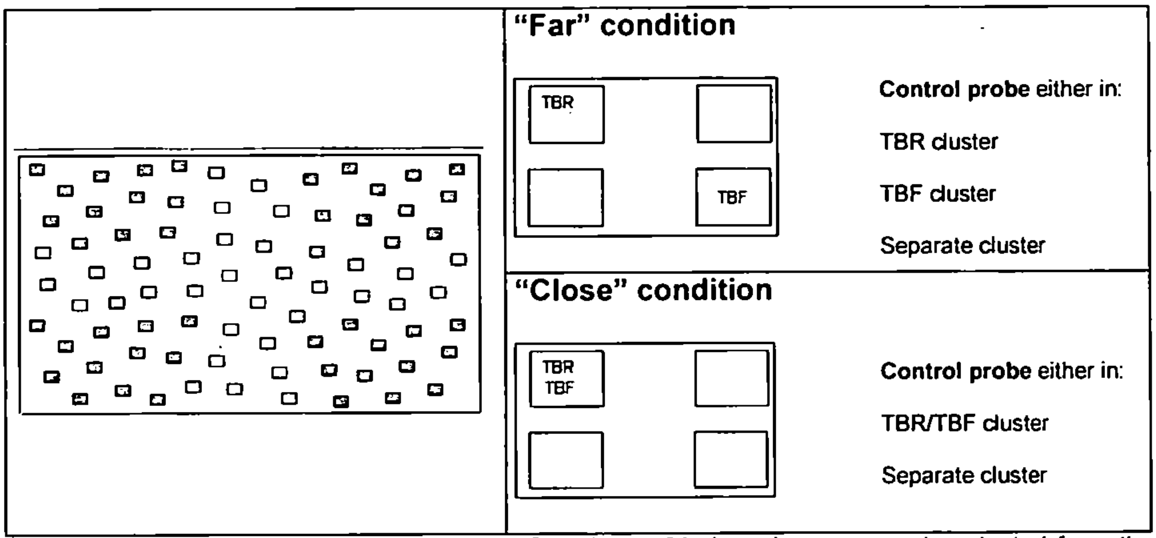

Figure 29: Spatial proximity manipulation in Experiment 3A. Locations were only selected from the clusters in the four corners (shaded squares). TBR and TBF locations were either selected from locations in separate clusters ("far" condition) or the same cluster ("Close" condition). The location of the control probe was also systematically varied in its proximity to the TBR and TBF set.

As shown in Figure 29 (p. 155), this matrix entailed 81 locations marked by squares[5]. However, only those 12 locations closest to each corner of the matrix were used throughout the experiment. The matrix was used to create two conditions:

(1) the *"close"* condition: Here, the TBR and TBF configurations were presented in the **same** cluster (e.g. both were shown in the top right cluster of the matrix).

[5] The use of a background grid containing 81 squares was reintroduced in this study because, comparable to Series 1, participants were required to judge the identity of a single location. As in Series 1, the grid was provided to give participants a frame of reference during encoding and rehearsal.

(2) the "*far*" condition: TBR and TBF configurations were shown in two **separate** clusters (e.g. TBF configuration presented in the bottom left cluster, TBR configuration presented in the top left cluster).

In addition, the position of the control probes was also manipulated. It would either appear (1) in the same cluster as the TBR configuration, (2) in the same cluster as the TBF configuration, or (3) in a separate cluster not occupied by either the TBR or TBF configuration.

As outlined above, it was predicted that perceptual grouping rules and the differentiated use of global or local processing would result in fast and accurate rejections of TBF and control probes when they were presented spatially distinct from TBR items, and poorer performance in trials where control and TBF probes were spatially confusable with TBR items. It was also hypothesized that performance with TBR probes would always be poorer in comparison to TBF and control probes, because regardless of its proximity to negative probes, participants would need to consult local processing strategies to verify the identity of the TBR probe.

<u>(a) Method</u>

(i) Participants

Twenty-one first-year students from the University of Plymouth participated in this study in exchange for course credit or monetary rewards. All participants reported normal or corrected-to-normal vision.

(ii) Materials

The experiment was presented on a 17" monitor (set to a resolution of 1024*768 pixels) using a program written in E-prime. In each trial, participants studied two frames (approximately 10 cm high, 18 cm wide) presented on top of one another. Each frame contained the same configuration of 81 squares (ca. 0.3 cm high, 0.5 cm wide) distributed in an evenly fashion. None of the squares were put together according to Gestalt principles, in an effort to prevent the use of verbal encoding. In each trial, only the 12 locations closest to each corner were used as potential stimuli and targets (see Figure 29). At test, only one frame (identical to those used for stimulus presentation) was presented at the centre of the screen.

(iii) Procedure

This study included a 2 (spatial segregation of TBR and TBF set: "close" versus "far" condition) x 5 (probe type: TBF, TBR, control probe presented in the TBR cluster, control probe presented in the TBF cluster, and control probe presented in a separate cluster) repeated measures design. The procedure was comparable to previous experiments, although this time, there was no long-term memory manipulation, so participants were not subjected to a training session prior to testing. In each trial, participants studied two frames containing the matrix outlined in Figure 29, presented on top of one another. The frames were identical except that in one, four squares were coloured in orange, and in the other, four squares were coloured in blue. The remaining squares remained blank. Participants needed to retain the position of the coloured squares. After 10400 ms, the two frames were temporarily replaced by a grey visual mask for 800 ms before returning to the screen, although this time, all the squares in the frames remained blank. Instead, the area around the frame changed into either blue or orange. This cue indicated whether participants had to remember the blue or the orange locations that they had studied previously. After 1300 ms, the two frames were replaced by a single frame presented in the centre of the screen. In it, one location was highlighted in black. As in the previous studies, participants needed to judge whether this location had been among the locations that they had to remember, pressing "y" on their keyboard if they thought it was a TBR location, and pressing "n" if they thought it was not. The screen displayed immediate feedback to this response for 1500 ms. After 1000 ms, the next trial was initiated.

There were 90 trials in total, 45 showing TBR and TBF locations in two separate clusters ("far" condition), and 45 trials with TBR and TBF locations sharing the same cluster ("close" condition). In each condition, every probe type was tested 15 times. For the control probe, this was broken down further: In 5 trials, the probe appeared in the same cluster as the TBR set, in 5 trials it shared the same spatial area with the TBF set, and in 5 trials it was presented in a separate cluster.

Trials corresponding to the "far" and "close" conditions were randomised across the study, to prevent participants being able to predict whether TBR and TBF sets would be in the same cluster and adjust their response strategy accordingly. In addition, there was no predictable order in which blue or orange squares were cued as TBR locations, and I also randomised the order in which blue and orange were used as colour markers in the two frames. The four clusters (and the locations within) were used evenly for each location set and probe type, to avoid any predictable pattern that participants might be tempted to follow.

(b) Results

Performance was analysed using a 2 (TBR-TBF proximity) x 5 (probe type) repeated-measures ANOVA. In the "close" condition, responses to control probes presented in the same cluster as the TBR set were collapsed with those to control probes presented in the same cluster as the TBF set. This was done because here, TBR and TBF sets were presented in the same cluster, so consequently, presenting the control probe close to the TBR set also meant that it was presented close to the TBF set.

Due to the complexity of the results, only those deemed relevant for this investigation are reported. For the remaining findings, please consult Appendices.

(i) Response times

In the response times data, the main effect of probe type was significant ($F_{1.5, 23.2}$ = 5.8, *MSe* = 430448.4, *p* = 0.015, see Appendices for a decomposition of this main effect). Participants were faster in the "far" condition (*M* = 949.5 ms, *SD* = 379.9) than in the "close" condition (*M* = 1015.8, *SD* = 311.5), although this difference was only marginally significant ($F_{1, 16}$ = 3.9, *MSe* = 48036.1, *p* = 0.066). Because the interaction between condition and probe type was significant ($F_{1.4, 22.4}$ = 5.4, *MSe* = 346756.0, *p* = 0.020), response times were analysed separately within "far" and "close" condition.

"Far" condition. In this condition, TBR and TBF items were presented in two separate clusters. Control probes were either presented in the same cluster as the TBR items, the same cluster as the TBF items, or in a cluster separate from both (see Figure 30, p. 160).

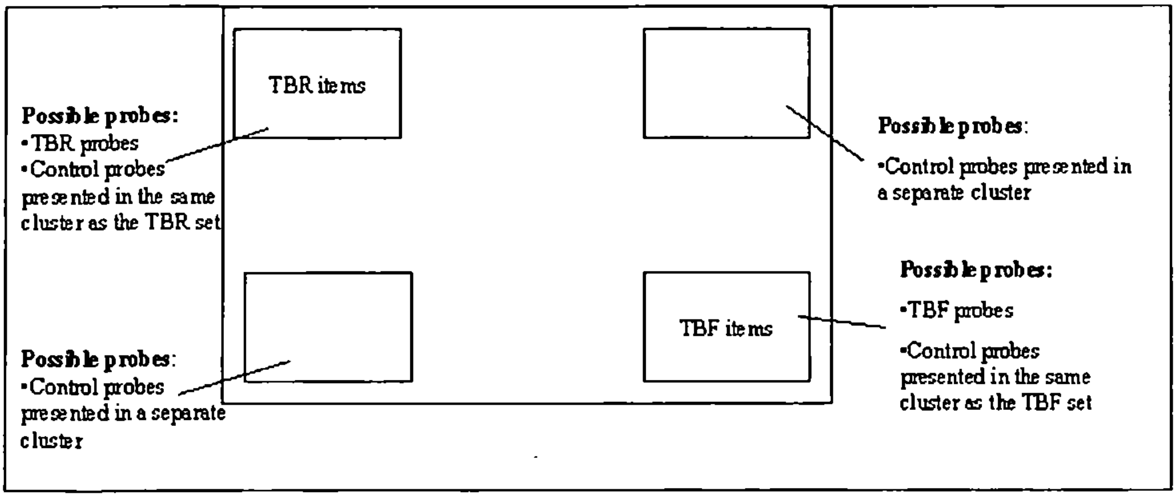

Figure 30: Example of the segregated positioning of TBR and TBF items and the corresponding possible locations of the five probe types in the "far" condition.

There was a significant main effect of probe type ($F_{1.2,\ 18.0}$ = 5.2, *MSe* = 818321.0, p = 0.032). Overall, responses were faster when the probe was positioned in a different cluster than the TBR items:

LSD comparisons suggested that response times were significantly slower with TBR probes than (a) TBF probes (p < 0.001), (b) control probes presented in a separate cluster (p < 0.001), and (c) control probes presented in the same cluster as the TBF items (p = 0.001). Control probes that were presented within the same cluster as the TBR set were rejected slower as well (p = 0.035, 0.042 and 0.043 in comparison to TBF probes, control probes in the TBF cluster and control probes in a separate cluster, respectively).

There were no significant differences between the three negative probe types that were segregated from the TBR set. In other words, participants were able to reject a negative probe quickly provided it was clearly distinct from the TBR set. If the probe was either a TBR probe or a control probe positioned close to the TBR set, response times increased.

As a consequence, no intrusion cost emerged. The comparison between TBF probes and control probes presented in the same cluster as TBR items was significant (p = 0.035) – but as visible on Figure 32 (p. 163), this difference pointed into the opposite direction of an intrusion cost.

"Close" condition. In the "close" condition, TBR and TBF sets were presented within the same cluster. Consequently, control probes could either appear in the same cluster as the TBR and TBF set, or in a separate cluster (see Figure 31, p. 161).

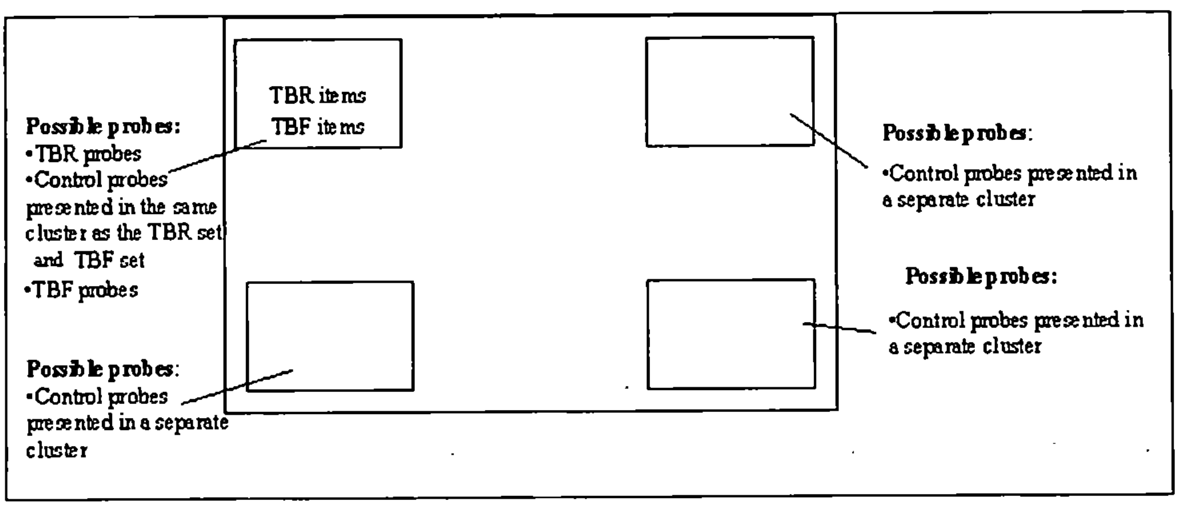

Figure 31: Example of the segregated positioning of TBR and TBF items and the corresponding possible locations of the five probe types in the "close" condition.

With a significant main effect of probe type ($F_{3, 60}$ = 11.6, *MSe* = 50121.9, $p <$ 0.001), response lags were longest in response to TBF probes and control probes presented in the same cluster as the TBR and TBF set (see Figure 32, p. 163). In other words, participants took longer to rejcet a negative probe if it shared the same cluster with the TBR set.

Response times were significantly longer in response to TBF probes than TBR probes (p = 0.028). Similarly, participants took longer to respond to control probes that had been presented in the same cluster as the TBR/TBF set than TBR probes, although this just missed significance (p = 0.089).

Response times were shortest with control probes presented in a separate cluster from the TBR/TBF set, and this was significant in comparison to TBR probes (p = 0.008), TBF probes (p < 0.001) and control probes presented in the same cluster as the TBR/TBF set (p < 0.001).

In summary, comparable to what was found in the "far" condition, response times were short if the negative probe was spatially distinct from the TBR probe. When the negative probe was presented within close proximity to the TBR set, response times increased. Thus, an intrusion cost was only found between TBF probes and control probes presented in a separate cluster (p < 0.001). The response times difference between TBF probes and control probes presented in the same cluster as TBR/TBF set pointed in the correct direction for an intrusion cost – however, this difference was nowhere near statistical significance (p = 0.396).

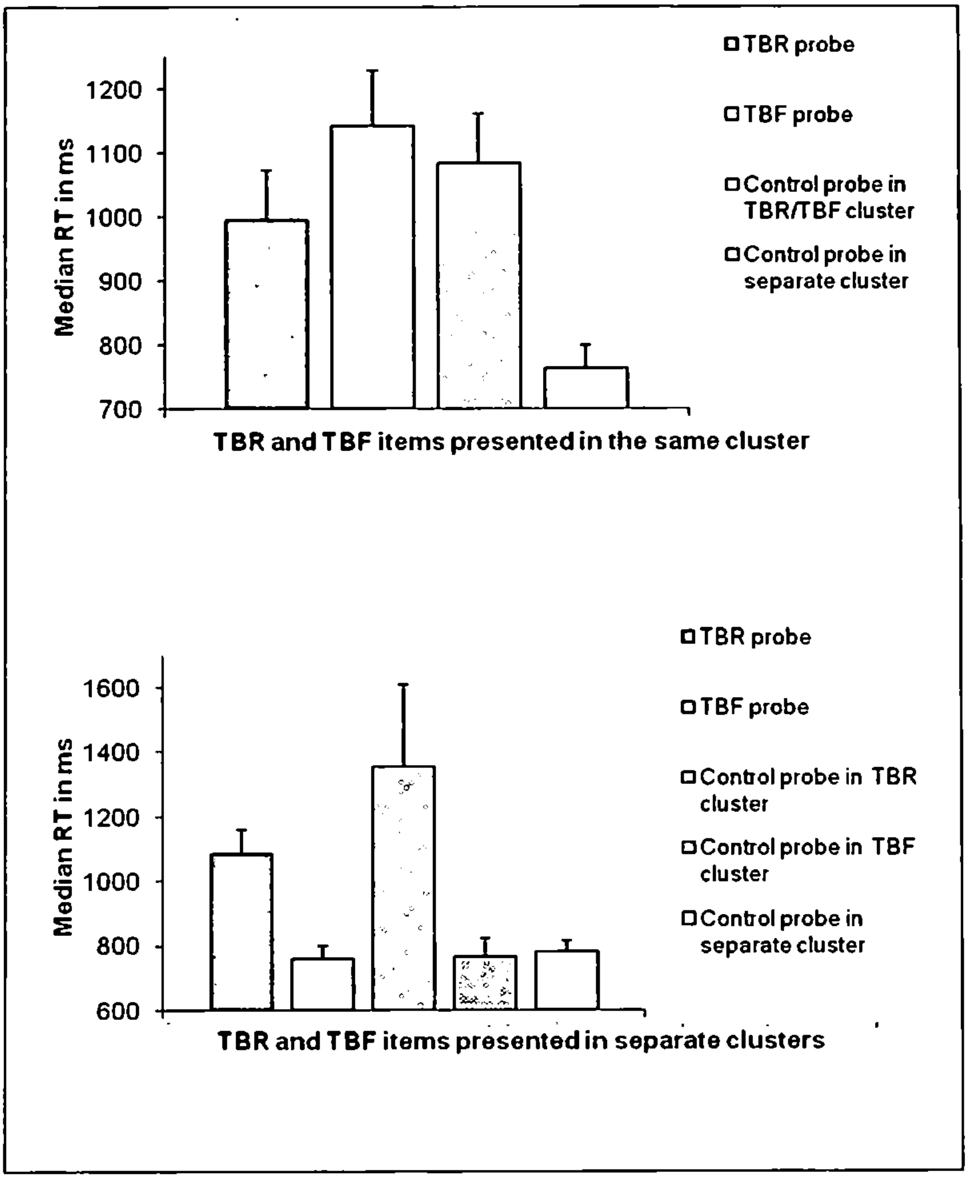

Figure 32: Median response times (error bars representing 1 standard error of the mean) to the five probe types with TBR and TBF items presented in the same ("close" condition) or separate clusters ("far" condition). The graphs show that negative probes – TBF and control probes - were rejected particularly fast if they were segregated from the TBR set. Note that in the graphs above, the ranges were extended in comparison to the previous experiments. This was done to accommodate the large standard error in one of the conditions.

(ii) Accuracy

For accuracy, there was a significant main effect of probe type ($F_{1.9, 37.1}$ = 37.9, *MSe* = 682.3, p < 0.001, see appendices for comparisons between probe types irrespective of "close" and "far" condition). Overall, participants were better in the "far" condition (M = 76.8%, SD = 15.9) than "close" condition (M = 68.0%. SD = 16.5; $F_{1, 20}$ = 16.2, *MSe* = 249.1, p = 0.001). The interaction between condition and probe type was significant ($F_{2.8, 55.3}$ = 33.7, *MSe* = 311.7, p < 0.001), meriting a separate analysis of responses in the "close" and "far" condition.

"Far" condition. To recapitulate once more, in the "far" condition, TBR and TBF items were presented in two separate clusters. Control probes were either presented in the same cluster as the TBR items, the same cluster as the TBF items, or in a cluster separate from both (see Figure 30, p. 160).

Overall, there was a significant main effect of probe type ($F_{1.9, 38.9}$ = 46.5, *MSe* = 565.9, p < 0.001, see Figure 33, p. 166). In this condition, all negative probes (with the exception of the control probe presented in the same cluster as the TBR set) were spatially segregated from the TBR set. Consequently, accuracy was ceiling for all of these negative probes, with no significant differences between them (see graph).

By comparison, performance was significantly lower with TBR probes (p < 0.001 in comparison to all three negative probe types that were clearly segregated from the TR set).

The poorest accuracy was found with control probes that had been presented in the same cluster as the TBR set. It was below chance (M = 36.2%, SD = 5.6) and significantly worse than performance in response to any of the other four probe types (p < 0.001 for all comparisons).

Due to high performance levels with the TBF probes, there was no evidence of an intrusion error in this condition.

"Close" condition. There was a main effect of probe type ($F_{1.7, 34.7} = 30.0$, $MSe = 469.6$, $p < 0.001$). Here, TBR and TBF configurations were presented in the same spatial cluster, and as a result, there were no performance differences between TBR probes, TBF probes, and control probes presented in the same cluster as the TBR/TBF set (see Figure 33, p. 166). Accuracy was quite weak with these probe types, with none of them exceeding 62%. By far and large, the best performance was accomplished with control probes presented in a separate cluster ($M = 99.0\%$, $SD = 1.0$), and this advantage was significant in comparison to all other probe types ($p < 0.001$).

An intrusion error emerged in a comparison between TBF probes and control probes presented in a separate cluster only ($p < 0.001$). There was no evidence for an intrusion error if both TBF and control probes were spatially confusable with the TBR set.

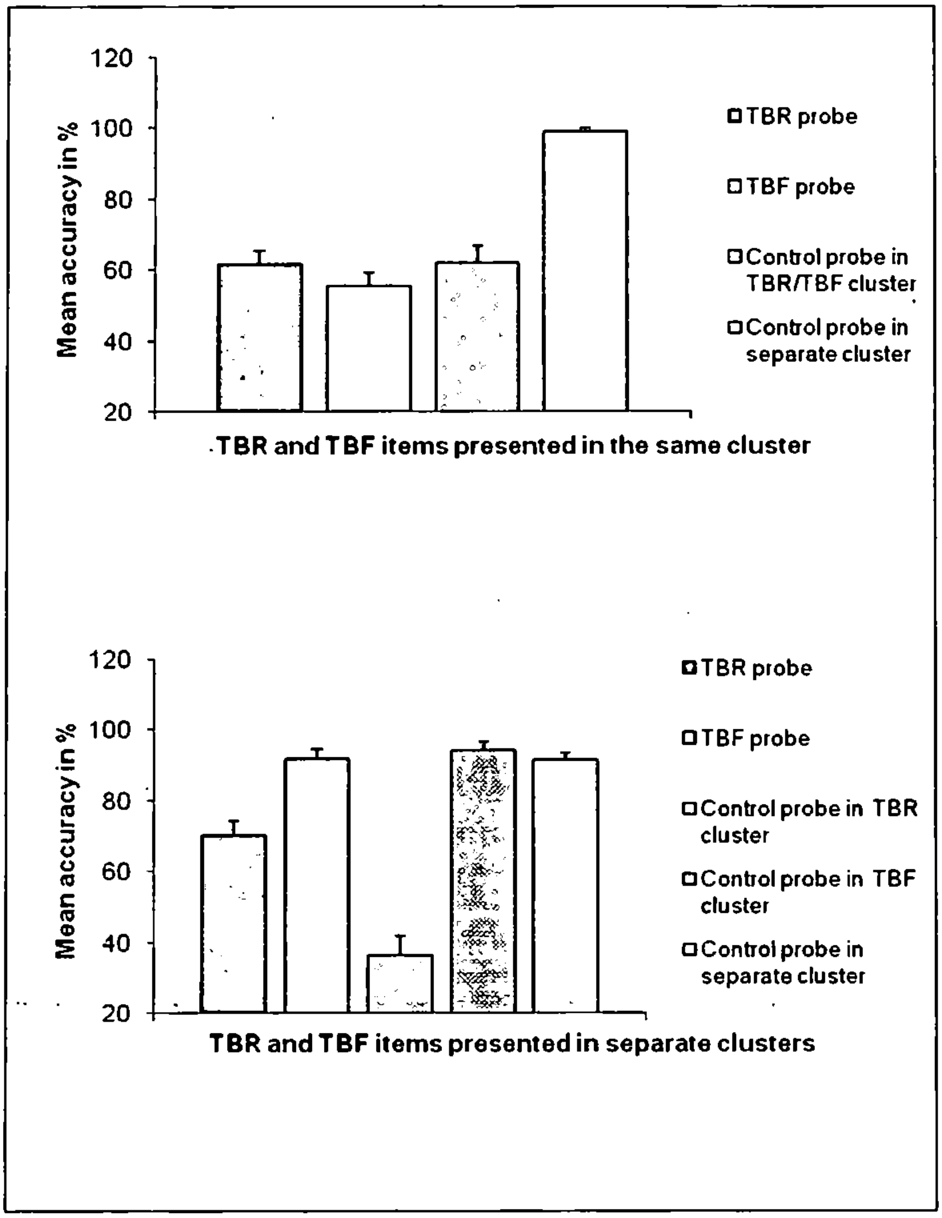

Figure 33: Mean accuracy (error bars reflecting 1 standard error of the mean) to the five probe types in trials with TBR and TBF items presented in the same cluster ("close" condition) and in two separate clusters ("far" condition) in Experiment 3A. Negative probes were rejected more accurately if they were visually segregated from the TBR items. Due to the large variation in performance in this experiment, the ranges of these graphs were extended in comparison to the previous experiments.

(c) Discussion

Results were largely in agreement with a priori predictions. Participants rejected control and TBF probes faster and more accurately if they were clearly segregated from the TBR items. Performance deteriorated when a negative probe was shown in the same cluster as the TBR set. Such findings support the hypothesis that response pattern observed with negative probes in previous studies may have been partially influenced by the spatial relationship between the negative probe and the TBR set. Results equivalent to an intrusion cost were only observed when the TBF probe was situated close to the TBR set with the control probe positioned away from the TBR set. Similarly, intrusion errors only emerged when the TBF probe was within the same cluster as the TBR set, while the control probe was presented away from the TBR set (this will be discussed in more detail below).

Previous research reviewed above indicated that global aspects are processed faster than local aspects (e.g. Fagot & Deruelle, 1997). In line with this theory, one could argue that because the TBF and TBR configurations were so obviously segregated in the "far" condition, participants were able to reject TBF probes quickly on the basis of straightforward global processing. When TBF and TBR sets shared the same spatial cluster, more care was required to ascertain that this particular location had not been occupied by a TBR item, thus requiring more elaborate local processing. Similarly, when control probes were presented in a separate cluster from the TBR configuration, rejecting them as not to-be-remembered was conducted through efficient global processes. When they were shown in the same cluster as the TBR items, however, a slower, more fine-tuned analysis was required to verify that this was not a TBR location.

Performance with TBR probes was once again poorer in comparison to other probe types, and similar in both "close" and "far" condition, which is in line with the idea that participants needed to employ precise local processing strategies to determine the identity of the probe, regardless of its spatial proximity to other items.

That participants appeared to adopt their processing strategies depending on the relative position of the TBR set was also apparent in a further result: They rejected control probes presented in the same cluster as TBR probes more accurately in trials where TBR and TBF sets shared the same cluster. One way to interpret this observation is that presenting the TBR and TBF sets in the same spatial area meant that participants had to process the sets' individual locations in order to keep the two sets apart, and to anticipate that the upcoming probe would require the same fine-tuned analysis, thereby boosting their inclination to reject the control probe on the basis of such local processing.

In contrast, when TBR and TBF sets were clearly segregated in separate clusters ("far" condition), participants were less prepared to deploy local processing strategies because it was so easy to differentiate between TBR and TBF sets on the basis of simple global processing already. As a consequence, performance deteriorated when the control probe was presented in the same cluster as TBR items. Put simply, when the control probe was presented in the same cluster as the TBR set, participants were more likely to incorrectly assume that this probe must have been to-be-remembered, because they had only processed the general area of where the TBR and TBF sets had been located, rather than their specific locations.

The ability to manipulate the extent to which a visual stimuli will be processed globally or locally is supported by research conducted by Robertson (1996) and Robertson, Egly, Lamb and Kerth (1993), who found that response times to a local target improved when participants were primed with a local target (and thus local processing) in the previous trial, and the same was true for global targets.

Such findings have important implications for the an interpretation of the intrusion cost in Series 1, where – similar to here - participants received single location probes, rather than entire configurations. In Experiment 3A, intrusion errors and intrusion costs only occurred between TBF probes that were within the same spatial cluster as the TBR set, and control probes that were spatially distinct from the TBR items. This might make it difficult to argue that in Series 1, elevated response times to TBF probes were a product of a familiarity signal that participants had to overcome in order to make a correct rejection response. In the light of findings in Experiment 3A, it seems more plausible to suggest that whenever participants found it harder to reject a negative probe, this was because it was spatially confusable with a TBR probe. This is also supported by the observation that in spite of their previous presentation, TBF probes that were spatially distinct from the TBR set were rejected rapidly and successfully[6]. Thus, it seems that the underlying processes of the effects observed in Series 1 are very different to the mechanisms that Oberauer (2001) proposed and may not actually reflect to what extent a no longer relevant spatial location leaves a trace in memory.

Of course, one limitation to this argument is that in Series 1, participants in both training and control condition were subjected to the same experiment containing the same trials with the same spatial makeup. The only difference between the two conditions was that in one of them participants had learned the test locations prior to the experiment. Apart from that, control and training condition involved exactly the same trials. Therefore, spatial proximity effects alone cannot explain why, for

[6] Furthermore, subsequent to their participation, a number of participants reported that they were quite aware of the fact that these probes were to-be-forgotten – but this did not hamper their ability to reject them, because they were so clearly segregated from the TBR set.

example in Experiment 1C, the intrusion cost only surfaced in the training condition, but not in the control condition. The next section discusses this issue in more detail.

(4.4) Training effects revisited

To recapitulate a point made prior to Series 2, it was suggested that the kind of familiarity triggering the intrusion cost in the previous studies may have not been induced by activated long-term memory traces, but by an assessment of processing fluency (evidence for this was found in Series 2). In other words, if participants were able to process a TBF probe in exactly the same way in which it had been processed earlier, this increased ease of processing, making the emergence of a familiarity signal more likely.

It was argued that in the experiments carried out for Series 1, an intrusion cost failed to emerge in the control condition because there was a processing mismatch between encoding and test. It is well established in the literature that spatial locations are encoded in configuration to one another (e.g. Jiang et al., 2000). Thus, participants may have encoded the TBR and TBF sets as a whole, whereas at test, the single location probe required them to decompose their mental image of the TBR configuration to determine the identity of the probe. This processing mismatch may have made it harder for them to rely on processing fluency as an indicator of familiarity, and, as a consequence, no intrusion cost occurred.

By contrast, an intrusion cost did emerge in the training condition of Experiment 1C and 1D, suggesting that the training manipulation may have somehow modified participants' processing strategies to suit the demands of the task. Specifically, one could argue that the training manipulation may have made participants more sensitive to storing the exact locations of the TBR and TBF configuration, rather than the general outline of each set. This approach would be more compatible to the way in which a single location probe would need to be processed, thereby enabling participants to make use of processing fluency as an indication of familiarity. This was not possible for participants in the control condition, whose configurational encoding strategies were at odds with the kind of processes required at test.

Such an observation can be combined with what has been discussed in Experiment 3A. It is possible to argue that what participants learned throughout the training session may in fact be the local, rather than global encoding of the test stimuli. In other words, learning the specific locations that would be used throughout the experiment prior to testing may have made participants more sensitive to maintaining the exact locations of the TBR and TBF set, rather than simply storing a more economical global outline of each set.

To investigate this, Experiment 1C was re-analysed taking spatial proximity into account. Its 45 trials were categorised into either "close" trials (in which TBR and TBF locations were spatially confusable) or "far" trials (in which TBR and TBF locations were clearly segregated). This was done using the following criteria: If the path connecting the individual TBR locations intersected more than once with the path connecting the TBF locations, and/or if there was less than 2 squares separation between any of the TBR and TBF locations, then the trial was classified as "close". In addition, I also categorised the control probes depending on whether they were close to the TBR set, close to the TBF set, or clearly separated from the two.

Based on these criteria, 30 of the 45 trials in Experiment 1C were classified as "close" (where TBR and TBF sets overlapped). Furthermore, only one out of the 45 trials presented control probes spatially segregated from both TBR and TBF set. In other words, in over 2/3 of the trials, participants were exposed to a scenario in which item-specific local processing was particularly crucial for a correct response, because TBR set and negative probes were spatially confusable.

Bearing in mind that statistical power was very limited in this observation, some of the findings (Tables 4 and 5, p. 172) may be worth reporting all the same to give a general idea of whether participants were more inclined towards local processing in the training than control condition.

Probes (% of trials)	**Accuracy (in %)**		**Response times (in ms)**	
	Training M (SD)	**Control** (M (SD)	**Training** M (SD)	**Control** M (SD)
TBR (22.2%)	70.5 (15.4)	70.3 (17.0)	1008.6 (176.5)	1034.6 (315.7)
TBF (26.6%)	73.8 (16.5)	64.6 (18.7)	964.7 (153.8)	1010.6 (390.8)
Control in the same cluster as TBR/TBF set (15.6%)	70.7 (19.9)	61.4 (19.7)	986.9 (207.4)	1021.0 (259.3)
Combined average of the above	71.7 (17.2)	65.4 (18.5)	986.7 (179.2)	1022.1 (321.9)

Table 4: Performance in "close" trials (where TBR and TBF sets spatially overlapped) in Experiment 1C. No trial featured a control probe that was segregated from the TBR and TBF set. In one trial, it was not possible to categorise the position of the control probe as either segregated or close to TBR and TBF set. This trial was excluded from the analysis.

Probes (% of trials)	**Accuracy (in %)**		**Response times (in ms)**	
	Training M (SD)	**Control** M (SD)	**Training** M (SD)	**Control** M (SD)
TBR (8.8%)	68 (19.9)	71.3 (26)	1110.8 (1821.1)	1114.5 (420.5)
TBF (6.7%)	93.3 (17.4)	88.3 (22.4)	827.7 (168.9)	738.9 (204.9)
Control in the same cluster as TBR set (2.2%)	75 (44.4)	50 (51.3)	1294.2 (1498.1)	1299.0 (915.5)
Control in the same cluster as TBF set (8.8%)	92.5 (14.3)	95 (10.3)	852.4 (206.8)	757.4 (228.3)
Control in the same cluster as TBR/TBF set (2.2%)	100 (0)	90 (30.8)	820.7 (165.3)	747.9 (318.2)
Combined average of the above	85.8 (19.2)	78.9 (28.2)	981.2 (772)	931.5 (417.5)

Table 5: Performance in "far" trials (TBR and TBF sets clearly segregated) in the re-analysis of Experiment 1C.

There was some evidence indicating that participants who had received training employed different processing strategies than those who had not. For example, the control condition rejected a TBF probe that was clearly segregated from the TBR set on average 88.8 ms faster than the training condition. The control condition was also 95 ms faster than the training condition to reject a control probe if it was not in the same area as any of the TBR items. Presenting the negative probe in another area on the screen than the TBR set requires little local processing, because it is so obvious that it does not match any of the TBR items. The control condition was clearly faster to realise this.

On the other hand, when the task demanded processing on a local level, participants with training performed better than those in the control condition: For instance, in "close" trials, participants in the training condition performed consistently better than those without training (see Table 4, p. 172). Presenting the TBR and TBF sets in the same spatial area requires the participant to store the exact locations of each set in order to discriminate between them. Participants in the training condition appeared to be better equipped to do so than the control condition.

Participants who had learned the test locations prior to the experiment also found it easier than the control condition to reject a control probe presented in the same area as the TBR set (75% versus 50% accuracy in training and control condition, respectively). This is another scenario where a fine-tuned analysis of the exact location of the probe is required in order to verify whether it had previously been occupied by a TBR item. The accuracy data showed that the training condition was again superior at this.

Combining these results with the finding that a disproportionate amount of trials required the use of local processing, a clearer picture emerged on the effects of the training session. In most trials, local processing was crucial to solve the task. It has been well documented, however, that at encoding, spatial locations are normally grouped rather than processed separately (Jiang et al., 2000). If the training session had modified participants' processing strategies from such a global to a more item-specific approach, then this should have improved their performance in those trials requiring local processing. Indeed, this is what the results suggested. Furthermore, the repeated use of local processing at encoding and at test should have increased the chances of detecting a familiarity signal, and, by association, the emergence of an intrusion cost.

Thus, the reason why a reliable intrusion cost emerged in this experiment may have been because the training manipulation altered participants' strategies to suit the kind of processing required in the vast majority of the trials. By contrast, in the control condition, participants encoded the stimuli in configuration, meaning that at test, this mental image had to be decomposed in order to make a correct response. Here, familiarity judgements could not be made on the basis of repeated processing, and as a consequence, no intrusion cost was observed.

In spite of this, Tables 4 and 5 (p. 172) demonstrate that both training and control condition performed better in trials where TBR and TBF configurations were clearly separated. Thus, even though participants in the training condition were more skilled at using local processing when required, it looked as though global processing still dominated in situations where this was a more appropriate approach (e.g. when the TBF probe was clearly separated from the TBR set).

In summary, findings from this reanalysis together with Experiment 3A indicated that when the paradigm discourages similar processing at encoding and retrieval, performance levels resembling an intrusion cost may in fact be the product of something other than a familiarity signal of the TBF probe (in this case, processing strategies to the different probe types may be mediated by the spatial composition of the TBR set, TBF set, and the probe). In order to get an intrusion cost comparable to the mechanisms suggested by Oberauer (2001), it may therefore be important to develop a scenario where participants are able to use the same type of processing at encoding and test, thereby enabling them to concentrate their judgement on feelings of familiarity. Experiment 3B explores this possibility in more detail.

(4.5) Experiment 3B

In contrast to Series 1, experiments in Series 2 presented a configuration of locations as probe. Here, an intrusion cost emerged even in the absence of training. Presumably, the underlying reasons for this are twofold. Intrusion costs are thought to occur when a TBF probe triggers a familiarity signal indicating that the item may be old, a signal that then needs to be overwritten by recollection (Oberauer, 2001). By presenting the TBF probe as a configuration, participants may have been able to detect familiarity signals on the basis of repeated processing fluency, because the TBF probe was identical to the way in which it was presented and processed at encoding (Jiang et al., 2000, see above). At the same time, intrusions may have been observable because the use of a configuration as probe may have led to results that were less contaminated by spatial proximity effects. This could be because participants would primarily process the identity (shape) of the configuration, with a somewhat smaller emphasis on its spatial position in the frame, or its relationship to other configurations. Of course, some impact of spatial proximity would remain, since participants would still need to remember where the configuration had been seen in the grid. Nevertheless, it is plausible to argue that with a configurational probe, participants would focus more on the outline of the configuration, and rely less on the spatial position of the probe, thereby reducing spatial proximity effects.

Experiment 3B explored this possibility, adopting the same principle methodology that was used in Experiment 3A, with the important exception that at test, an entire configuration of locations was presented as probe. As before, there were two conditions: Trials presenting TBR and TBF configurations in the same cluster ("close" trials) and trials in which TBR and TBF configurations were placed in two separate clusters. Control probes were once again presented either in the same cluster as the TBR configuration, in the same cluster as the TBF configuration, or in a separate cluster. While some spatial proximity effects were expected (e.g. performance was predicted to be better in "far" trials where there was a clear spatial segregation of TBR set and negative probes), these were predicted to be much smaller than what was found in Experiment 3A.

(a) Method

(i) Participants

23 undergraduate students from the University of Plymouth participated for course credit or monetary rewards. None of them had participated in my previous studies. No participant reported colour blindness, and they all had normal or corrected-to-normal eyesight.

(ii) Materials

The materials were identical to Experiment 3A.

(iii) Procedure

The procedure was identical to Experiment 3A, but the probe was presented as a configuration of four locations. This configuration either matched the TBR set, the TBF set, or was made up of a configuration with four locations not featured in either TBR or TBF set (control probe).

(b) Results

A 2 (condition: "close" versus "far" trials) x 5 (probe type: TBR probe, TBF probe, control probe presented in the same cluster as TBR configuration, control probe presented in the same cluster as TBF configuration, and control probe presented in a separate cluster) repeated-measures ANOVA was used to analyse the results. Only those findings are reported here that are considered relevant, for all other results, please consult Appendices. As in Experiment 3A, in the "close" condition, responses to control probes presented in the same cluster as the TBR configuration were collapsed with those presented in the same cluster as the TBF configuration.

(i) Response times analysis

Across the two distance conditions, there was a highly significant main effect of probe type ($F_{4, 88}$ = 5.1, *MSe* = 1813.7, $p < 0.001$) in the median response times data (see appendices for a decomposition of this main effect). There was no significant main effect of condition ($F_{1, 22}$ = 0.012, *MSe* = 24442.7, p = 0.914), indicating that overall, response times remained unaffected regardless of the spatial relationship between TBR set and negative probes. The interaction between probe type and condition was, however, significant ($F_{4, 88}$ = 6.6, *MSe* = 18625.6, $p < 0.001$), meriting a closer comparison of probe types within "close" and "far" condition (see also Figure 29, p. 155).

"Close" condition. In trials presenting TBR and TBF configurations in the same cluster, there was a significant main effect of probe type ($F_{2.1, 47.1}$ = 4.8, *MSe* =

25783.0, $p = 0.011$). Overall, LSD tests suggested that participants were faster with control probes than the other two probe types, regardless of where the control probe was presented: Control probes presented in a segregated cluster elicited shorter response lags than TBR probes ($p = 0.049$) and TBF probes ($p = 0.018$). Similarly, response times to control control probes presented in the same cluster as the TBR/TBF set were shorter than to TBR ($p = 0.013$) and TBF probes ($p = 0.012$).

In other words, regardless of where the control probe was positioned in relation to the TBR set, an intrusion cost always emerged – responses were consistently slower with TBF than control probes.

"Far" condition. In the "far" condition, TBR and TBF sets were presented in separate areas of the grid. Control probes either appeared in the same cluster as the TBR set, the same cluster as the TBF set, or in a separate cluster. As in the "close" condition, there was a reliable main effect of probe type ($F_{2.7,\ 59.9} = 6.4$, MSe = 31745.4, $p < 0.001$).

Response times were generally shorter with negative probes when they were clearly segregated from the TBR set: Participants took longer to reject a control probe when it was presented in the same cluster as the TBR configuration than if it was presented in a separate cluster ($p = 0.001$). Furthermore, TBF probes were rejected faster than control probes that were situated in the same cluster as the TBR items ($p = 0.003$). Importantly, as Figure 34 (p. 179) illustrates, response times to TBF probes were such that no evidence for an intrusion cost emerged anywhere.

Responses were slower with TBR probes than negative probes only when the latter were presented in segregation from the TBR set ($p = 0.001$, 0.015 in comparison to TBF probes, and control probes presented in a segregated cluster, respectively).

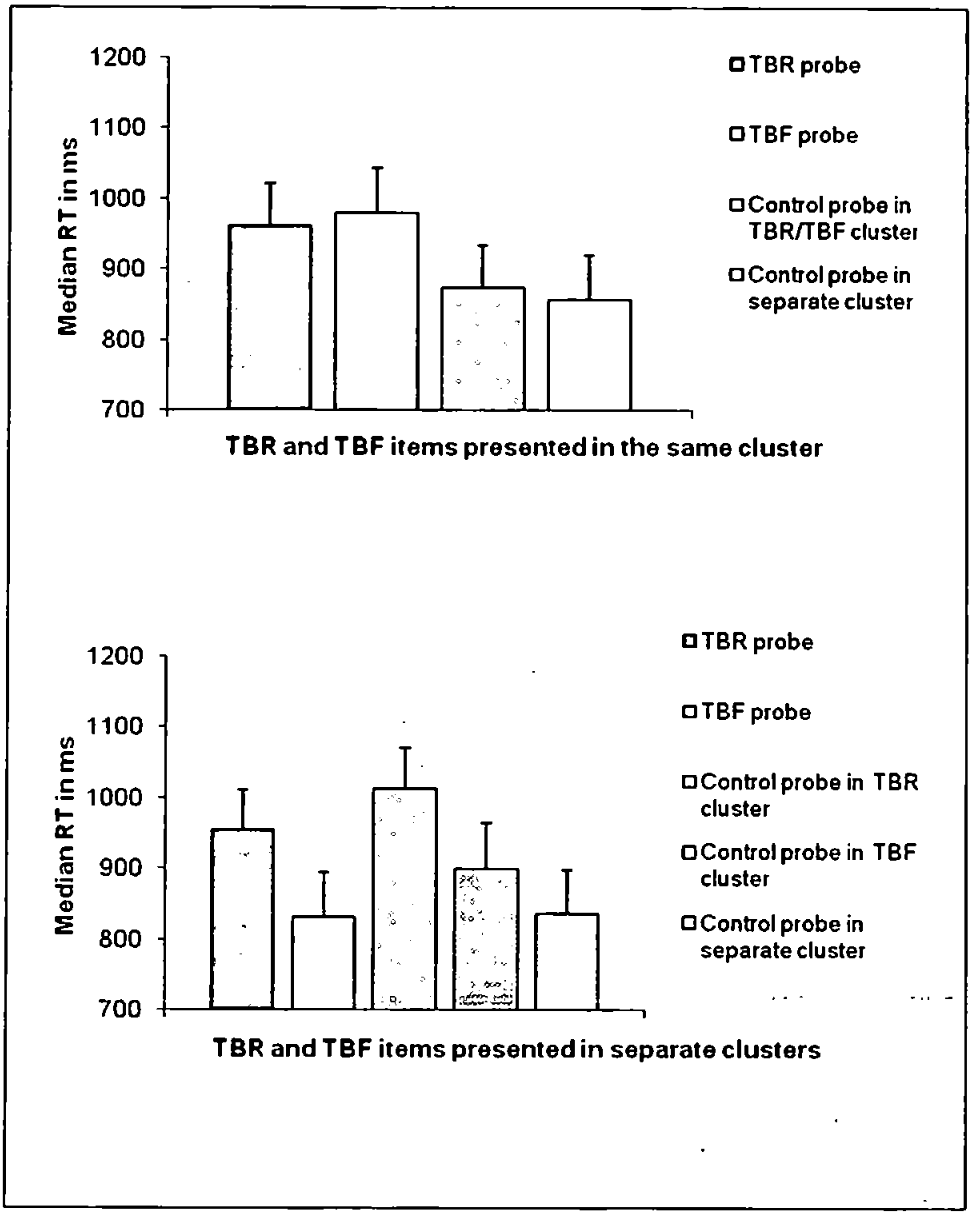

Figure 34: Median response times (error bars representing 1 standard error of the mean) to the five probe types with TBR and TBF items presented separately ("far" condition) and in the same cluster ("close" condition), Experiment 3B. When TBR and TBF set were presented separately, all negative probes were rejected faster if they were segregated from the TBR set. However, in the "close" condition (where TBR and TBF items were presented in the same cluster), control probes were rejected fastest regardless of their relative position to the TBR items. Results resembling an intrusion

cost were only observed in the "close condition", where TBF probes were rejected less quickly than control probes, regardless of where they were positioned in relation to the TBR set.

(ii) Accuracy analysis

Comparable to what was found in the response times data, there was a significant main effect of probe type ($F_{2.2, 49.1}$ = 7.7, *MSe* = 390.6, p = 0.001, see Appendices for further details), but no reliable differences between "close" and "far" condition ($F_{1, 22}$ = 0.9, *MSe* = 184.1, p = 0.354) in the accuracy data. A reliable interaction between probe type and condition ($F_{4, 88}$ = 10.8, *MSe* = 100.1, $p < 0.001$), again justified a closer inspection of performances in each condition (see also Figure 35, p. 182).

"Close" condition. There was a reliable main effect of probe type ($F_{3, 66}$ = 9.9, *MSe* = 145.8, $p < 0.001$). Performance levels did not fall below 80% for any of the probes, so the highly significant main effect was solely attributable to the near ceiling performance with control probes presented in a segregated cluster (*M* = 97.4%, *SD* = 6.9), which outperformed TBR probes (*M* = 80.6%, *SD* = 12.7; $p < 0.001$), TBF probes (80.6%, *SD* = 15.3; $p < 0.001$), and control probes presented in the same cluster as the TBR and TBF set (*M* = 85.7%, *SD* = 16.2; p = 0.002). There were no observable differences elsewhere. Thus, an intrusion error only emerged in a comparison of TBF probes and control probes that were clearly segregated from the TBR set (p < 0.001).

"Far" condition. The main effect of probe type was highly significant ($F_{2.5, 54.0}$ = 9.3, *MSe* = 292.9, $p < 0.001$). All negative probes were rejected with high accuracy provided they were clearly segregated from the TBR set: Accuracy was lower with control probes presented in the same cluster as the TBR set than with control probes presented in a segregated cluster ($p < 0.001$), control probes presented in the same cluster as TBF probes ($p < 0.001$) and TBF probes (p = 0.001). As Figure 35 (p. 182)

indicates, performance was quite high in response to TBF probes, and consequently, there was no statistical evidence for an intrusion error.

Performance was poorer in response to TBR probes than those negative probes presented in a separate cluster, although this was only significant in comparison to control probes presented in the same cluster as the TBF set (p = 0.005) and TBF probes (p = 0.006).

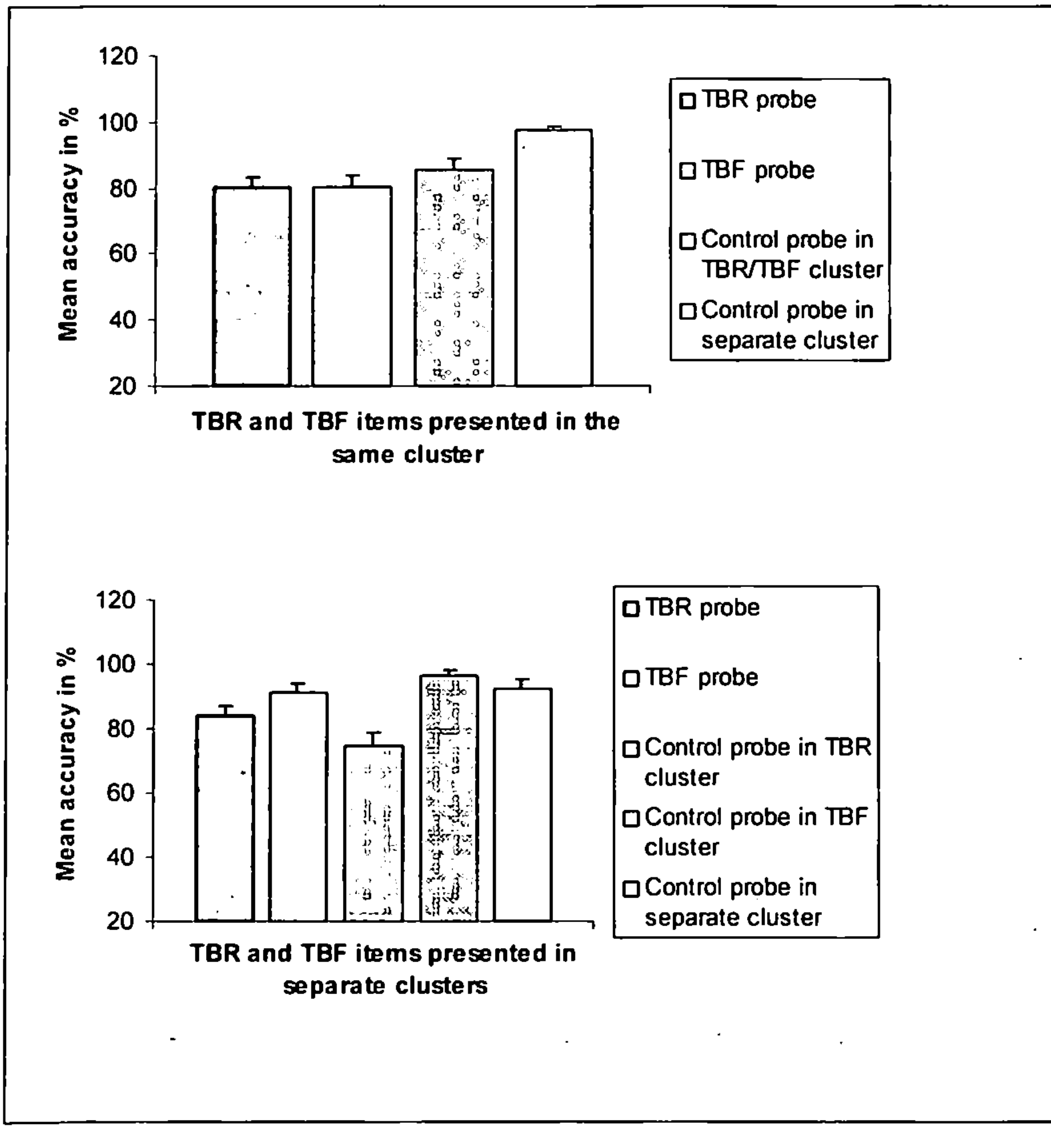

Figure 35: Mean accuracy (error bars representing 1 standard error of the mean) to the five probe types with TBR and TBF items presented in the same ("close" condition) or separate clusters ("far" condition), Experiment 3B. On the whole, accurately rejecting negative probes was more successful if the negative probe was clearly segregated from the TBR set. Results resembling an intrusion error were only observed in the "close" condition (TBR and TBF items presented in the same cluster). Here, performance was poorer in response to TBF probes than control probes presented in a separate cluster.

(c) Discussion

Overall, results provided some evidence that the spatial proximity between TBR set and negative probes had less impact on performance when participants responded to a complete configuration of spatial locations, rather than a single subcomponent. The underlying reasoning for this assumption was that participants would focus more on retaining the shape of the configuration, rather than its precise position on the screen, thereby reducing the importance of spatial information.

Indeed, if the spatial position had played a large role in the processing of the control probe, then presenting it in the same area as the TBR and TBF configuration should have slowed down performance in comparison to trials in which the control probe was clearly segregated from the two sets. This was, however, not the case: An analysis of response times in the "close" condition (where TBR and TBF sets were presented in the same cluster) revealed that regardless of the proximity between control probe and TBR configuration, participants always rejected the control probe faster and more accurately than TBF probes. Thus, whether or not the control probe was spatially confusable with the TBR configuration bore no relevance to the speed with which participants rejected it. This also meant that it was possible to observe an intrusion cost that was independent from the spatial composition of the trial. Control probes were always rejected faster and more accurately than TBF probes.

Overall, results had much less variation than in Experiment 3A where participants had responded to single locations, rather than complete configurations. For example, in Experiment 3A results varied between 765.6 ms and 1355.0 ms. In Experiment 3B, on average, response times only had a numerical variation of less than 200 ms (between 831.1 ms and 1013.4 ms). This also supported the theory that presenting an entire spatial configuration at test reduced the impact that spatial proximity could have on response times. Regardless of the relationship between TBR set and negative probes, response times remained relatively constant.

In spite of the above, there was also evidence that, depending on the scenario, spatial relationships between TBR and TBF configurations still created some bias in participants' processing strategies. For example, in trials where TBR and TBF configurations were presented in separate clusters ("far" condition), performance with negative probes was superior when the probe was clearly segregated from the TBR set. Such results could indicate that when TBR and TBF configurations were within the same cluster ("close" condition), participants anticipated that the probe may also appear in this cluster, thereby possibly investing more effort in encoding the exact locations of each configurations. When TBR and TBF configurations were presented in separate clusters, on the other hand, participants may have simply relied on the spatial information (e.g. that the red set was in the top left corner, but the blue set in the top right corner), rather than concentrating on the actual locations. Thus, because they had only memorised the general area where the TBR configuration had appeared, this would explain why they were more likely to commit an error if a control probe appeared in the same cluster as the TBR items.

Furthermore, intrusion errors and costs were still affected by spatial proximity. An intrusion cost was observed only in the "close" condition where TBR and TBF items were presented in the same cluster. In the "far" condition, where TBF configurations were shown in a separate cluster from the TBR set, participants were able to reject TBF probes quickly and accurately due to their apparent distance to the TBR set. Such findings indicate that regardless of whether a memory or processing trace remains, if the TBF material is too distinct from the TBR set, then it is not possible to observe an intrusion cost. Thus, a mere familiarity signal triggered by the TBF probe is not sufficient for the emergence of an intrusion cost – the material must also be relatively similar to the TBR items.

Of course, if this is the case, then this raises the question whether it is at all possible to attribute the intrusion cost to a familiarity signal triggered by the TBF probes. Perhaps, the only reason why participants took longer to reject TBF items was because the close spatial proximity led them to confuse TBF with TBR items. However, results clearly demonstrated that familiarity of the test item still had a role to play: In the "close" condition (TBR and TBF sets presented in the same cluster), an intrusion cost emerged even when the control probes was presented in the same cluster as the TBR set. If delayed rejections of negative probes occurred because they were confused with TBR items, then this should have affected control and TBF probes alike. This was not the case, however: When TBF and control probes were presented within close proximity of the TBR items, performance deteriorated only in response to TBF probes.

Thus, Experiment 3B demonstrated that in spatial memory, an intrusion cost relies not only on a familiarity signal of the TBF probe, but also on the spatial proximity of a TBR configuration. If the TBF probe is clearly segregated from the TBR item, then the familiarity signal on its own is not sufficient to trigger an intrusion cost.

In addition, Experiment 3B indicated that when the task allowed participants to focus more on the overall shape of the configuration rather than the spatial information of its subcomponents, spatial proximity effects created less interference in the data. Results in the "close" condition suggested that when this bias was removed, intrusion costs emerged regardless of the spatial relationship between the TBR set and negative probes. However, when the composition of the TBR and TBF configurations at encoding primed participants towards focusing solely on the spatial attributes of the sets (in the "far" condition), spatial proximity continued to affect performance.

Such results also have implications for the design of future nonverbal memory studies. Experiments 3A and 3B demonstrated that results can be heavily contaminated by the spatial relationship between the test stimuli. Ways to avoid such interference could involve counter-balancing the spatial compositions used across trials or designing trials in which spatial attributes do not provide sufficient information. In the "close" condition, for example, the fact that TBR and TBF configurations were presented in the same cluster meant that participants had to encode visual aspects of the configuration – merely remembering where the configuration had been allocated in the frame would have not been sufficient to solve the task.

(5) GENERAL DISCUSSION

With the exception of Palladino et al. (2003) and Cornoldi and Mammarella (2006), most previous research exploring the fate of no longer relevant material has focused on verbal memory. The studies reported here were driven by the goal to address this shortcoming and explore several aspects underlying deliberate forgetting in spatial memory. In doing so, this thesis also touched upon several other factors that may be involved in our ability to ignore no longer relevant information in memory.

Research by Oberauer (2001) indicated that when a recently learned stimulus is declared to be no longer relevant, it nevertheless remains activated in memory for quite some time, even when attention is deployed elsewhere. In Oberauer's study, this surfaced through the emergence of an intrusion cost – participants took longer to reject previously seen TBF probes than new control probes as not to-be-remembered. At the same time, only the size of the TBR set affected performance, which was interpreted as evidence that while TBR items were actively rehearsed in the capacity-limited direct access region of working memory, TBF material had been transferred to the activated subset of long-term memory, where it remained available but no longer readily accessible.

Oberauer's interpretation of the intrusion cost relied on the assumption that working memory is an integrated component of long-term memory and, secondly, that intrusions occur because the TBF probe triggers a feeling of familiarity through activated long-term memory traces that must be overwritten through recollection. The first part of this thesis explored whether having a long-term memory representation of the no longer relevant item really does play a crucial role in the emergence of the intrusion cost.

(5.1)The involvement of long-term memory in the intrusion cost

To briefly recap, in a previous investigation contrasting a verbal and nonverbal version of the modified Sternberg task (Burghardt, 2003), an intrusion cost emerged only with verbal material. While this observation could be understood as further evidence for the dissociation of verbal and nonverbal memory, it could on the other hand also be a reflection of the relative degree to which participants held stable long-term memory representations of the test items.

In Oberauer's framework, intrusion costs are the outcome of TBF traces remaining activated in long-term memory in spite of participants' attempts to focus their attention on the TBR items only. Perhaps, the reason why an intrusion cost failed to emerge with the spatial material in my pilot study was because participants had experienced no previous exposure to the test material, thereby lacking the long-term memory support required to prevent a rapid decay of the TBF traces once attention is moved elsewhere. Indeed, further evidence supporting such notion was the finding that performance was typically just as high with TBF probes as control probes, suggesting that participants treated them similarly.

(a) Evidence from Series 1

To explore this line of reasoning further, Series 1 involved a number of experiments manipulating the degree to which participants had formed stable long-term memory representations of the spatial test stimuli, with an implicit approach through repeated exposure (Experiment 1A), followed by an explicit training manipulation in Experiment 1B-1E.

Taken together, results in Series 1 show quite clearly that while long-term memory may play a role in our ability to discard no longer relevant material, it has been difficult to find evidence for this involvement in a consistent manner. In Experiment 1A, participants in the learning condition were exposed to the same principle locations over the entire experiment, while the control condition was tested with two varying location sets. It was argued that repeatedly using the same location set would gradually familiarise participants with the locations, thereby creating traces in long-term memory. The finding that performance levels were comparable regardless of condition suggested that this may have not been very successful. Furthermore, no intrusion cost was observed in any of the conditions.

A partial explanation for the failure to find any evidence that participants had internalised the test locations may have been that in each trial, participants only saw a small subset of the test locations, and never all of the test locations together. This is quite different to Chun and Jiang's study (2003), in which complex spatial arrays were repeatedly presented to participants. Using this methodology, Chung and Jiang successfully found evidence that participants had implicitly retained them over long periods of time.

Consequently, in Experiment 1B, the implicit training manipulation was replaced by an explicit approach. Participants learned the test locations prior to testing, and it was also verified that their long-term memory had stored these locations throughout the entire experiment. Nevertheless, no intrusion cost emerged.

A closer investigation of Experiment 1A and 1B threw up another potential factor that may have contaminated the results. In both experiments, TBR and TBF sets were initially presented in one frame on the screen. Such a presentation may have made it difficult for participants to create separate representations for each set in memory, and, once the "forget" command had been given, to selectively discard one of the two sets. Under such conditions, it is hard to predict what strategies participants may have used to solve the task.

To avoid this problem, Experiment 1C was an almost identical replication of Experiment 1B, save for one important modification: TBR and TBF sets were now presented in two separate frames to maximise the salience of each set. Indeed, in line with a priori predictions, this paradigm change enabled the emergence of an intrusion cost among those participants who had been familiarised with the test locations, but not among those who had not learned the test locations prior to testing.

The intrusion cost was again replicated under the same conditions in Experiment 1D. In addition, Experiment 1E replicated Oberauer's findings (2001) that only the TBR set size affected performance – the size of the TBF set had little or no impact on participants' accuracy or response times. According to Oberauer, such an outcome is evidence that subsequent to the "forget" instruction, only the TBR material remained in the capacity-limited direct access region, while the TBF material was moved to the activated subset of long-term memory.

The emergence of the intrusion cost in Experiment 1C and 1D lent, at least to some extent, support for Oberauer's notion that the intrusion cost is determined by the relative degree to which the no longer relevant information is supported by traces in long-term memory. The fact that the intrusion cost failed to surface unless TBR and TBF items were visually segregated indicated that in long-term memory, no longer relevant information must be clearly separated from the material that one wishes to maintain. In Oberauer's working memory model, this means that in order for TBF material to be dropped from the capacity-limited direct access region, it is important that it is not linked to TBR material. In verbal memory, this is supported by

Golding et al.'s research (1994), who found that it is not possible to selectively ignore words if they are semantically related to TBR words.

Nevertheless, other results were not as clear-cut. Experiment 1D was designed to rule out that the intrusion cost was a product of a more general effect of the training manipulation (making participants more sophisticated at this type of task in general), rather than an enhancement of the long-term memory traces corresponding to the test items. To do so, participants were trained on one location set, but the experiment also presented another set on which they had not been trained. If the intrusion cost was reliant on existing traces in memory corresponding to the test material, then it should only emerge in those trials containing the location set that participants had memorised. Indeed, the intrusion cost was only found with the location set that participants were familiar with – but alongside, an intrusion error (poorer performance with TBF probes relative to control probes) also emerged in trials containing the set on which participants had not been trained. This is a surprising result that is in conflict with the idea that intrusions can only emerge if the decay of TBF material is prevented by the resilience of their corresponding traces in long-term memory.

Furthermore, even though Experiment 1E provided evidence that only the TBR set size had an impact on performance, an intrusion cost failed to emerge in this study, regardless of the fact that participants had been trained on the location set prior to testing.

There are several ways to interpret these conflicting results. One might argue that perhaps, the resilience of the memory traces created with the training manipulation was not nearly as profound as that of traces corresponding to items that we use on a regular basis every day. Oberauer (2001) used high frequency words, items that should enjoy a very stable representation in long-term memory. In the studies presented in this thesis, the spatial material was rather unusual for participants, and as such, even with the training manipulation, the corresponding memory traces were probably not nearly as resistant to decay as those in Oberauer's study. As a consequence, no longer relevant material may have decayed faster in the present studies, preventing the occurrence of an intrusion cost.

Indeed, it proved to be quite difficult to develop a paradigm where participants hold strong and resilient memory traces of the test items in one condition, and little or no representations of the same items in another. In the present studies, the degree to which the long-term memory representations of the test items differed between learning and control condition may have been quite small, but this was sufficient to observe performance differences between the two groups in at least two of the studies. With caution, this could be interpreted as some evidence that long-term memory has an impact on the speed with which we can discard no longer relevant material.

Nevertheless, there is an alternative way to explain why prior learning led to the creation of an intrusion cost. This competing view – which places little importance on the role of long-term memory – is described below.

(b) Alternative views challenging the involvement of long-term memory

Even though Experiment 1C and 1D gave some indication in favour of the view that the intrusion cost is determined by the existence of long-term memory traces slowing down the decay of no longer relevant material, the remaining experiments in this thesis provided an alternative interpretation of the findings in Series 1. First of all, results in Series 2 demonstrated quite clearly that an intrusion cost can emerge even if participants had never seen the stimuli before (and thus had not formed any long-term memory traces of the items). This was accomplished by abandoning the single location probe and instead showing the probe in exactly the same way in which the stimuli had been presented and encoded (i.e. in a configuration of four locations). These results challenge the argument that an intrusion cost can only occur if pre-existing long-term memory traces trigger a familiarity signal in response to a TBF probe, which then needs to be overwritten by conscious recollection processes. Instead, it was argued that when stimuli are not represented by matching traces in long-term memory, perhaps the type of familiarity driving the intrusion cost is based on a processing fluency judgement (this will be discussed in more detail below).

Therefore, while Series 1 offered some evidence that long-term memory may play a role in inducing the familiarity required to trigger an intrusion cost, combining these results with Series 2 indicated that this familiarity can also be triggered by other means, particularly in the absence of pre-existing long-term memory representations slowing down the decay of TBF material.

As a consequence, it is also not clear whether the training manipulation led to an intrusion cost because it helped participants create long-term memory traces of the stimuli. For example, in Experiment 1D (where participants were trained on one location set, but then tested on a new location set as well), intrusions errors were even observed with locations on which participants had not been trained. Experiment 1D also showed that having learned one location set did not benefit performance on that location set alone – accuracy and response lags were similar with both location sets.

These results suggested that the training manipulation had a more general effect on performance, rather than specifically enhancing participants' memory of the items on which they had been trained. In the third part of this thesis, the nature of this effect was explored in more detail. Experiments in Series 3 tested whether performance patterns reflected perceptual processing strategies that varied depending on the relative position of the negative probe in comparison to the TBR set. Specifically, Series 3 provided some evidence to suggest that the training manipulation may have created an intrusion cost because it changed participants perceptual processing strategies (see below).

(c) Conclusion

The two previous sections show that it was difficult to draw a firm conclusion regarding the impact of prior learning on the intrusion cost. A clear interpretation of the data was complicated by a number of perceptual mechanisms that may have affected the observed outcome. Series 1 demonstrated on a number of occasions that it is possible to mediate the intrusion cost through prior learning of the test items. In conjunction with results found in Series 2 and 3, however, it seems unlikely that this mediation was due to the creation of long-term memory representations.

Several findings are in support of this and these have been discussed at length above. However, to briefly recap the most important ones: First of all, intrusion costs occurred in Series 2 and 3 regardless of the fact that participants had never encountered the items before. Furthermore, in Experiment 1D, the impact of prior learning also translated in some respects to locations that participants had not been trained on. Lastly, Series 3 indicated that the relative speed with which participants respond to an item was particularly susceptible to the spatial relationship between

TBR and TBF items, again showing that participants' memory of the test item may not be the most crucial factor when predicting their performance.

Instead, results in Series 3 indicate that the main reason why prior learning helped to create an intrusion cost was because this prior learning altered participants' perceptual strategies, rather than the state of their long-term memory. Put in other words, the results presented here suggested that prior learning enabled participants to develop more appropriate problem-solving strategies for the task, rather than stronger memory representations of the test items in comparison to the control condition (see below for a more detailed analysis).

Nevertheless, it would seem rather presumptuous to altogether reject the idea that long-term memory has no part to play in the relative success of deliberate forgetting in short-term memory .There is ample evidence elsewhere that long-term memory affects short-term memory performance, and that it is harder to retain items for which we do not have long-term memory representations (e.g. Bower & Winzenz, 1969; Hulme et al., 1991). Thus, by the same token, it should also be easier to ignore items that are not represented in long-term memory. The studies presented here provide limited evidence that this may be the case, but future research may need to affirm this further, for example through the use of more direct measures of memory (e.g. recall) to explore to what extent TBF items remain available in memory if they are not represented in long-term memory.

Perhaps, with the type of paradigm used here, the functional difference in terms of long-term memory representations was too small between the two conditions to detect an effect. As was discussed earlier, it has proven difficult to develop an empirical test enabling a comparison of performance on an item for which participants have no previous memory in one condition, but a firmly established long-term memory representation in the other condition. However, a comparison of such extremes might be a requirement in order to establish the precise impact of long-term memory on the intrusion cost. Future research may need to continue to explore this matter.

(5.2) Perceptual mechanisms governing the intrusion cost

The literature offers a number of processes involved in the perception and encoding of spatial information, including perceptual grouping (De Lillo, 2004, Jiang et al., 2000) and local versus global processing (e.g. Navon, 1977, Fagot & Deruelle, 1997). Specifically, these studies suggested that spatial items located within close proximity to one another are typically encoded as one configuration (De Lillo, 2004). Furthermore, it is possible to analyse a visual presentation using either global (acknowledging the overall outline or shape of the object) or local processing (studying the individual components into which the object can be decomposed). Research has indicated that adult humans prefer global over local processing, meaning that in a visual analysis, processing of the overall image of a presentation takes priority over its detail features (Navon, 1977).

(a) Spatial proximity effects on the intrusion cost

In Series 3, the literature mentioned above was reviewed in order to argue that the spatial composition of the TBR and TBF set may have also had an impact on the speed with which participants responded to a target. It was suggested that whenever the negative probe was spatially distinct from a TBR set, it would be rejected fairly easily, while presenting negative probes in the same spatial field as TBR items would slow down response times.

This was based on two assumptions: On the one hand, presenting the TBR and TBF sets in two distinct corners of the screen presumably facilitated participants' ability to selectively encode and maintain the two sets. At test, it should then be a lot easier to identify whether the probe was in a position previously occupied by a TBR item.

A second assumption was that whenever the negative probe was clearly separated from the TBR items, there was no necessity to carry out time-consuming local processing of the exact location(s) in order to realise that this probe was not to-be-remembered. If, on the other hand, the negative probe was spatially confusable with a TBR item, then local processing should be required to ensure that this specific location had not been occupied by a TBR item. Based on this rationale, response times should be heavily influenced by the spatial relationship between the TBR set and negative probes.

In Experiment 3A (in which the spatial composition of TBR and TBF sets was systematically varied, as well as the distance of the control probe to the two sets) there was corroborating evidence for this idea. An intrusion cost only emerged in situations where the TBF probe was spatially confusable with TBR items (resulting in slower response times) and the control probe was spatially segregated from the TBR set (resulting in faster response times). This is in line with the idea that whenever the negative probe was clearly separated from the TBR set, participants were able to reject it quickly on the basis of fast global processing, but when the negative probe was in the same spatial area as a TBR item, more elaborate local processing was required to analyse whether a TBR item had previously been positioned on this location.

Thus, response times appear to partially rely on the spatial relationship between relevant and no longer relevant locations. This poses a considerable problem for the intrusion cost, because it would suggest that prolonged response times to TBF probes relative to control probes are not in fact an indication of the relative degree to which the TBF items are still remembered. Instead, such results could have been the outcome of simple perceptual mechanisms facilitating the ability to distinguish between TBR and no longer relevant items.

(b) Stimulus-probe processing congruence

The type of variable processing strategies described above may have been aggravated by the way in which the probe was presented. In Experiment 3A, probes were presented in the same fashion as in Series 1, whereby participants rated a single location at test. However, showing this rather than the entire TBR or TBF configuration would have constituted a mismatch to the way in which participants would have encoded the two sets originally (i.e., in configuration, cf. Chun & Jiang, 2003).

Thus, in order to analyse the identity of this single location probe, participants would have needed to decompose the configurational image of the location sets stored in their memory. This would have been particularly important whenever the negative probe was spatially confusable with a TBR item. If, on the other hand, the negative probe and TBR configuration were separated on two opposite ends of the screen, no such decomposition of the mental image would have been necessary – it would have been quite clear that this one location could not have possibly been a member of the TBR configuration. Indeed, the results summarised in the previous section confirm that this is a plausible assumption. [7]

If, on the other hand, the probe was presented in the same way in which participants had seen and encoded the original TBR and TBF sets (i.e. in configuration), then one could assume that spatial proximity may have not had the same impact on participants' processing strategies. Encoding the TBR and TBF configuration as a whole corresponds in many ways to global processing (identifying the outline, rather than the details of a shape). Thus, regardless of where the negative probe was positioned in relation to the TBR configuration, participants would have primarily focused on its shape in order to verify its identity. Decomposing the mental image using local processing would have not necessarily been a requirement to judge whether this probe matched a TBR configuration. If this was the case, then one could predict that response times to negative probes would remain unaffected by their relative distance to a TBR configuration.

To demonstrate this, Experiment 3B was run as an almost exact replication of Experiment 3A, although this time, participants were presented with configurational rather than single location probes. Here, perceptual grouping benefits remained (participants rejected negative probes faster if they were spatially segregated from the TBR set), however, the effect was much smaller, and control probes in particular were rejected quickly regardless of their relative position to the TBR set. In addition, the congruent stimulus and probe presentation improved both accuracy and

[7] Furthermore, Experiment 1E showed clear set size effects of the TBR configuration – performance deteriorated if participants had to retain four, rather than two TBR locations. This indicated that participants may have felt compelled to decompose the mental image of the TBR configuration at test in order to check whether the probe matched any of the TBR locations. Future research may find it worthwhile to explore whether the same set size effects could be found if the probe was presented as a configuration. Theoretically, if both stimulus and probe are presented and encoded as a whole configuration, the number of locations within said configuration should not have such a big impact on performance.

response times in comparison to previous studies showing single location probes, supporting the idea that participants used similar global processing strategies both at the time of encoding and test.

Thus, in summary, Experiments 3A and 3B provided some evidence for the notion that the way in which the probe was presented may have impacted on participants' processing strategies, and, by association, response times to the different probe types. This is an important observation because, as results from Series 2 show, in order to obtain an authentic intrusion cost, it may be particularly vital to present the probe in exactly the same way in which participants encoded and maintained the original stimuli (this will be discussed in more detail below).

(c) Perceptual processing changes caused by the training manipulation

Finally, Series 3 of this thesis also discussed the underlying effects of the training manipulation used in Series 1. Results from Experiment 1D showed that the effects of the training manipulation were not confined to trials involving the learned location set; but also translated to other sets that participants were not familiar with. This suggests that learning the test locations may have not induced a change in performance on the basis of creating of long-term memory traces, but that a different factor may have come into play.

A competing theory why the training manipulation succeeded in triggering the intrusion cost may be that it altered participants' perceptual strategies. Perhaps, learning the locations used in the study made participants more sensitive to processing the spatial locations individually on a local level, which appears to be a more suitable approach when the probe is presented as a single location (as done in all Series 1 experiments).

Indeed, a re-analysis of Experiment 1C on the basis of the spatial composition of the TBR and TBF set supported this idea. In situations where performance would have benefited from global processing (e.g. when the negative probe was clearly segregated from the TBR set), participants in the control condition outperformed those in the learning condition. On the other hand, in trials where the TBR and TBF set were spatially confusable (thereby requiring local processing to ascertain whether this location had been occupied by a TBR item), performance was overall better in the learning than control condition. In other words, those participants who had not learned the test items prior to participation were better in trials where the negative probes were clearly segregated from the TBR set, but not as successful in situations where the task demanded elaborate local processing. Those participants who had been trained, on the other hand, performed better in trials requiring a precise local processing to rule out that this was a location previously occupied by a TBR item.

Thus, when interpreting the results of Series 1, it is important to bear in mind that the observed performance patterns may not actually provide an indication of the extent to which TBF representations were still available in memory. Instead, results from the re-analysis of Experiment 1C combined with conclusions drawn from Series 3 are in support of the notion that the training condition may have altered participants' general processing strategies. Learning the exact locations that would be used in the experiment may have made participants more sensitive to encoding each individual location of the presented configurations, rather than just maintaining the overall outline (the reason why an intrusion cost would emerge under such conditions is going to be explained in more detail in the following section).

(5.3) Familiarity in intrusions: Long-term memory versus processing fluency

In Series 2, the single location probe was replaced by a configurational probe. In addition, participants did not receive any pre-test training to familiarise themselves with the test locations of the experiment. If the existence of long-term memory traces corresponding the test items was the underlying factor driving the intrusion cost, then clearly no such effect should have been observed. In fact, an intrusion error (poorer performance in response to TBR than control probes) surfaced in Experiment 2A, and an intrusion cost was measured in Experiment 2B (where the background grid was removed to maximise the salience of the presented configurations). The intrusion cost was then replicated once more in two cue-probe duration conditions (650 ms and 2600 ms) in Experiment 2C. Put simply, Series 2 demonstrated that it is possible to observe a stable intrusion cost even in the absence of pre-existing long-term memory traces.

Such results have implications for the kind of familiarity underlying the intrusion cost. Two competing theories were presented with slightly different perspectives on the underlying mechanism which produces familiarity. One account argues that feelings of familiarity occur because the repeated processing of the item facilitates perceptual fluency (Whittlesea, 1993). Such an explanation does not require the presence of long-term memory representations matching the to-be-recognised stimulus. By comparison, Oberauer's account incorporated a familiarity theory as postulated in Yonelinas' dual process theory of recognition (Yonelinas, 1994), whereby familiarity ratings are based on a comparison of the stimulus with the content of long-term memory. If an activated representation is found that matches the stimulus, it is recognised as "old", if no such activated representation is detected, the item is thought to be new.

In Oberauer's framework, intrusions are explained by TBF memory traces benefiting from long-term memory support. Due to such support, the activation of TBF representations does not decay immediately, triggering a feeling of familiarity when a TBF probe is presented. This familiarity initially inclines participants to identify the item as "old" and thus to-be-remembered. Therefore, in order to make the correct rejection response, participants must consult more time-consuming recollection processes, leading to longer response lags than those found with control probes.

If the support of long-term memory was the crucial factor in familiarity causing the intrusion cost, then no intrusion cost should have occurred with items for which participants had no existing long-term memory traces. Yet, the results found in Series 2 contradict this prediction. Specifically, even though participants were unfamiliar with the test items - thereby making an involvement of long-term memory unlikely –an intrusion cost emerged all the same.

The fact that an intrusion cost was observed even with items that were not represented in long-term memory provided further evidence that perhaps, long-term memory is not as crucially involved in preventing the decay of no longer relevant material as predicted. A competing account by Whittlesea and associates (e.g. Whittlesea, 1993) - in which familiarity is not reliant on such memory traces, but is deduced from an increase in processing fluency – may account for such findings. To recap once more, this theory argues that feelings of familiarity are created when the processing of an item is perceived to be facilitated due to its previous processing in the past. Consequently, perhaps because their unfamiliarity with the stimuli made them unable to rely on the resilient activation of corresponding long-term memory traces, participants may have based their familiarity ratings on processing fluency.

At this stage, it is important to bear in mind findings by Westerman et al. (2002) who found evidence suggesting that processing fluency loses its value as an indicator of familiarity if there is a mismatch between stimulus and probe presentation. Thus, the equivalence between encoding and retrieval processes may be an important determinant of whether an intrusion cost will occur. In Series 1, for example, participants presumably encoded the original stimuli in configuration, but were then presented with a single location at test, a scenario that presumably requires elaborate local processing. In these studies, no intrusion cost occurred unless participants took part in a training manipulation prior to testing. Therefore, the reason why an intrusion cost occurred only here may be because such training altered participants' perceptual strategies from a global to a local level, thereby synchronising processing at encoding and at test.

In Series 2, on the other hand, stimuli and probe were presented as a configuration, enabling participants to process both in the same manner. This overlap in processing style may have facilitated participants' ability to refer to processing fluency as an indicator of familiarity, thereby increasing the likelihood of obtaining an authentic intrusion cost.

(a) The importance of processing congruence for the intrusion cost

Processing congruence may be an important factor for obtaining an authentic intrusion cost for a number of reasons. On the one hand, presenting the probe in such a way that prevents us from processing it in the same way as it was initially encoded may reduce the familiarity value, which is in line with research by Westerman et al. (2002) and Geiselman and Bjork (1980, cited in Mandler, 1980), who argued that reducing the similarity between encoding and test compromises familiarity. This poses a particular problem when, as was the case in the present studies, there are no long-term memory representations to fall back on. In such a scenario, feelings of familiarity are created because the repeated processing of a previously encountered item increases processing fluency. If participants engage in different processing strategies at test, such a re-processing advantage cannot occur, thereby reducing feelings of familiarity.

Furthermore, in particular with regard to exploring intrusions in spatial memory, findings from Series 3 suggested that the synchronisation of encoding and probe processing could reduce the influence of other confounding variables such as perceptual grouping. In Experiment 3A, where participants studied entire configurations before responding to a single location probe, intrusion costs appeared to be the artificial product of simple perceptual mechanisms, whereby negative probes were rejected quickly if they were clearly separated from any of the TBR items, and slowly if they were spatially confusable with a TBR item. Such a response pattern clearly has nothing to do with whether or not participants had retained the TBF locations in memory.

In Experiment 3B – using configurational probes - an intrusion cost emerged regardless of the relative position of negative probes in relation to the TBR set. Because in this study, there was a match between stimulus and probe presentation, this would suggest that this enabled participants to make authentic familiarity judgements that were independent from the perceptual layout of the trial.

Thus, ensuring that encoding and probe scenarios are as closely matched as possible may reduce the influence of confounding variables whilst maximising familiarity values, thereby providing a less ambiguous picture of the degree to which no longer relevant items have an impact on performance. Future research may seek to explore whether similar stimulus-probe congruence effects can also be found in verbal memory (for example, by contrasting visual encoding and visual probe presentation in one condition with visual encoding and auditory probe presentation in another).

(b) Implications for Theories of Familiarity

It is important to note that while the processing fluency account of familiarity provided a better fit for the data in the present studies, they were not designed to make definite claims about the nature of familiarity, or indeed, whether familiarity is a fixed process, or whether it can take various forms depending on the type of task that is executed.

For example, it should be noted that a strict segregation of the two accounts of familiarity presented here may perhaps prove to be somewhat counterproductive. The perceptual fluency theory argues that to trigger feelings of familiarity, an item does not need to have a firmly established representation in long-term memory – it is simply the facilitated repeated processing of the item that produces the familiarity signal. However, what this approach does not explicitly resolve is how and where the details of this repeated processing are stored.

It is of course possible to speculate that the facilitation of processing may occur in ways that are similar to what is typically observed in priming. One might, on the other hand, also reason that such information could in fact be held in long-term memory. This would suggest that even in the perceptual fluency account, long-term memory might have a role to play: it may store procedural information about how we processed the item during our first encounter, thereby giving us a reference point enhancing the repeated processing of the item. The current experiments do not have the required scope to distinguish between these two possible explanations. Future research will need to explore whether it is at all possible to merge these two competing accounts of familiarity into one, or which of them may withstand further empirical scrutiny.

At this point, a further possible solution is that the mechanism triggering feelings of familiarity is dependent on situational factors. With the material used in Oberauer's study (high frequency words), it makes sense to rely on an account in which familiarity is triggered by activated traces in long-term memory. However, as shown in Series 2 and 3, feelings of familiarity can arise even with items lacking such long-term memory support, and in such instances, familiarity may be the product of perceptual fluency. This indicates that interchangeable forms of familiarity may exist, although this would need to be explored further in future research.

(5.4) Verbal versus Spatial Directed Forgetting

Due to an ongoing debate in the literature regarding memory's architecture in general, and the dissociation of verbal and nonverbal memory in particular, this research project was initially driven by the aim to investigate whether the intrusion cost previously observed in verbal memory would also occur in spatial memory.

Concentric memory models such as the Focus of Attention Model presented by Oberauer (2001) would describe memory as a large system in which memory traces are connected comparable to a neural network. In such a model, all currently activated traces in long-term memory combined form working memory. Furthermore, memory traces are organised in such a way that related items share stronger links to one another than weakly related items. As a consequence, if one item is activated, some of its activation will be shared with strongly related neighbouring traces.

Even though such models would argue against the idea that memory is split into verbal and nonverbal subcomponents, what results in this thesis made clear is that the memory processes associated with verbal and nonverbal stimuli may not always be comparable, simply due to the very nature of the two types of stimuli. On the whole, the present studies indicated that, provided that the properties of the spatial testing material are matched as closely as possible to those used in the verbal studies, it is possible to observe nonverbal intrusions that are similar to those in verbal memory.

(a) Long-term memory

The spatial material used in the present studies differed from the verbal stimuli used by Oberauer in terms of their representation in participants' long-term memory. As discussed in previous sections, Oberauer's stimuli were made up of high-frequency words for which participants had strong long-term memory representations. In contrast to this, participants had never come into contact with any of the stimuli used in the present studies.

As has been discussed earlier, Oberauer's interpretation of the intrusion cost relied on the pre-existence of long-term memory traces slowing down the decay of TBF material. Results from previous pilot studies (Burghardt, 2003) indicated that without such long-term memory support, no intrusion cost emerged with nonverbal material. However, evidence from Experiment 1C and 1D suggested that once participants had learned the test locations prior to testing, it was possible to observe an intrusion cost with spatial material. Such results would suggest that, provided verbal and nonverbal memory are made more comparable in terms of their representation in long-term memory, processes underlying deliberate forgetting are comparable regardless of modality.

Nevertheless, as has been discussed extensively above, other results from Series 1 and 2 were not as clear-cut. The training manipulation did not always prove to be successful, and in Experiment 1D (where participants were trained on only one of the two location sets on which they were tested), intrusion errors even emerged in the location set that participants had not been trained on. This indicated that perhaps, the training manipulation did not actually lead to an intrusion cost because it created pre-existing long-term memory traces, but because it altered participants' processing strategies (see below).

Furthermore, Series 2 showed that even when participants had not familiarised themselves with the spatial stimuli prior to testing, it was possible to observe an intrusion cost. It was suggested that perhaps, when pre-existing long-term memory traces are lacking, one may still be able to develop feelings of familiarity based on processing fluency judgements. On the other hand, it is of course also possible to speculate that similar mechanisms exist in verbal memory. This would indicate that Oberauer's interpretation of the intrusion cost was based on the incorrect assumption that the underlying familiarity signal was determined by the detection of an activated memory representation corresponding to the TBF material.

Future research will need to clarify further what type of familiarity is driving the intrusion cost, and whether this familiarity is comparable in nonverbal and verbal memory.

(b) Stimulus-probe processing congruence

Another factor that may have created a discrepancy between the verbal material used by Oberauer (2001) and the type of stimuli used in Series 1 was the fact that in Oberauer's study, participants were able to process the verbal items in exactly the same way at encoding and at test. In contrast, in Series 1, probes were presented as single locations, while the original stimuli had been presented as complete configurations of four locations. Thus, participants may have initially encoded the TBR and TBF configurations as a whole, but were then forced to decompose their mental image of these configurations in order to verify whether the probe had been among the TBR locations. Indeed, once participants were able to make use of the same processes at encoding and at test, Series 2 demonstrated that intrusion costs emerged with nonverbal stimuli just in the same way as with verbal stimuli.

(c) Set size effects

Experiment 1E was designed to investigate whether set size effects were comparable with those observed by Oberauer (2001), who found that in verbal memory only the size of the TBR set had an impact on performance, while varying the number of TBF locations had no effect on response times or accuracy. Experiment 1E produced converging results, with only marginal effects of the TBF set size on overall performance.

On its own, this would indicate a further similarity between directed forgetting processes in verbal and nonverbal memory. However, it is still possible that the underlying processes explaining why the TBF set size had no impact on performance may in fact be different to what has been found in verbal memory.

To briefly recap, Oberauer (2001) proposed that performance remained unaffected by the size of the TBF set was because of its transferral to the activated subset of long-term memory, where they remain activated, but not readily accessible. Only the TBR items continue to be rehearsed in the direct access region. Because this region is supposedly constrained by capacity-limits, this may explain why an increase in TBR items would result in a deterioration of performance.

As discussed earlier, other results in this thesis indicated that perhaps, the processes underlying the type of familiarity triggering the intrusion cost may in fact be very different to those proposed by Oberauer (2001). Specifically, it was argued that when items are not well represented in long-term memory, the familiarity signal driving the intrusion cost may not be based on the remaining activation of memory traces corresponding to the TBF material, but instead on the ease of repeatedly processing an item seen before. If this is the case, then it is not a requirement that the TBF items remain activated in long-term memory. Instead, the simple fact that participants had processed the item before may be sufficient to create a feeling of familiarity. Such reasoning would indicate that it is not obligatory for the TBF material to remain activated in long-term memory to trigger a familiarity signal. All that would be required is the previous processing of the material in order for a familiarity signal to occur. Future research may need to explore this idea in more detail.

(d) TBR-TBF set dissociation

Results presented in Series 3 suggested that, comparable to what has been found in verbal memory, the first step towards successfully ignoring no longer relevant material is the ability to dissociate it from material that is still goal-relevant. If there is a clear dissociation between TBR and TBF items, then it is easy to exclusively focus on TBR items only. If, however, TBR and TBF sets are confusable – either due to semantic associations, as in verbal memory (Golding et al., 1994), or perceptual proximity, as in nonverbal memory (Series 3) – it becomes increasingly difficult to abandon the TBF material and selectively rehearse TBR material only.

Experiment 3A demonstrated that negative probes were rejected more easily if they were clearly separated from the TBR configuration, than if they were located in the same spatial area as the TBR items. There are two ways in which this could be explained: On the one hand, the literature has shown that spatial location within close proximity to one another are typically grouped together (De Lillo, 2004). Consequently, if TBR and TBF locations were presented in two opposite corners of the screen, participants should have found it easier to encode and maintain these two sets separately, and then, following the "forget" prompt, to selectively rehearse the TBR set only. If, on the other hand, both TBR and TBF sets were presented in the same area, then the fact that we prefer to group neighbouring locations into one configuration may have made it impossible for participants to form two separate memories corresponding to the two sets.

The second explanation is based on local and global processing research (e.g. Navon, 1977). To recap, global processing is thought to be involved in the identification of the general outline of a stimulus, while more time-consuming local processing is required for an analysis of its detail features. Applying this paradigm to the present findings, this may indicate that participants took longer to reject a negative probe within close proximity to a TBR location because such a scenario would have required them to consult elaborate local processing in order to confirm that this location had not been occupied by a TBR item. Presenting the negative probe far away from any of the TBR locations, on the other hand, would have not required any local processing – the clear spatial segregation made it very clear that this probe could have not been any of the TBR locations.

In summary, even though the very nature of spatial information may mean that the underlying processes are different to what may be found in verbal memory, in both modalities, deliberate forgetting may be influenced by the degree to which TBR and TBF material are related. If the two sets are intertwined, then it becomes very difficult to selectively rehearse one set only and to distinguish between relevant and no longer relevant information at test.

Such findings lend support for the idea that memory is composed of a large network of interconnected memory traces (see Oberauer's Focus of Attention Model). When two items are strongly linked, then it becomes very difficult to selectively maintain the activation of one trace, since some of the activation would automatically be passed on to all neighbouring traces. Findings by Golding et al. (1994) and Experiment 3A support that this is the case in verbal and nonverbal memory alike – in both studies, performance deteriorated whenever TBR and TBF sets were closely related due to either semantic or perceptual similarities.

(e) Summary

The studies reported here suggested that some similarities between verbal and nonverbal forgetting processes exist, which is in favour of memory models that do not rely on separate storage systems for different modalities but instead argue for a system that flexibly adjust its mechanisms depending on the nature of the stimuli that it needs to process.

Concentric models such as Oberauer's (2001, 2002) have scope to integrate such findings by assuming that both verbal and nonverbal memory are governed by the same principal system. Indeed, considering that we are capable of combining verbal and nonverbal information quite effortlessly in our everyday life is more in line with a unitary approach to memory in which processing rules are flexibly adapted to the properties of the stimulus, than a multi-component model in which verbal and nonverbal memory are structurally and functionally segregated. Future research needs to explore in more detail to what extent there are further forgetting processing analogies in verbal versus nonverbal memory.

(5.5) Oberauer's working memory model

Part of this investigation was also designed to explore if Oberauer's model of working memory provided a good fit for data gathered with spatial stimuli lacking the same amount of long-term memory support that the verbal material in his own study had. This section gives a brief summary of the main results together with a discussion querying whether the intrusion cost can truly be regarded as evidence for Oberauer's model, and whether the current version of this model is a conclusive account of memory.

(a) Converging findings that the intrusion cost is evidence for Oberauer's model

As outlined above, Oberauer's model views working memory as an integrated part of long-term memory, comprising three subcomponents: The capacity-limited direct access region, holding those items that are within the individual's awareness, the activated subset with all activated items that are not used (unconstrained by capacity), and the focus of attention, containing the one item that is currently being processed.

To provide evidence for his model, Oberauer referred to his studies involving the intrusion cost (i.e. slower response times to TBF than control probes when rejecting these as not to-be-rememebred). According to his interpretation, intrusion costs occur because the TBF material is moved into the activated subset of long-term memory, where the traces remain activated, but not readily accessible. When a TBF probe is presented, the activated memory trace triggers a familiarity signal indicating that this item is old. In order to make the correct rejection response, this familiarity signal needs to be overwritten by recollection processes indicating that this probe was not to-be-remembered.

Oberauer (2001) found that only the TBR set size had an impact on performance, suggesting that while active rehearsal of the TBR material continues in the direct access region, TBF material is moved to the activated subset. Furthermore, Oberauer found that intrusions remained observable even after 5000 ms, indicating that TBF memory traces did not decay rapidly. Some of the present studies provide similar results in – for example, in Experiment 1E, performance was affected only by the size of the TBR set.

A crucial aspect of Oberauer's interpretation of the intrusion cost was the argument that TBF memory traces are not erased immediately once attention is deployed elsewhere because they are supported by long-term memory. Accordingly, it was hypothesised that items that participants were not familiar with would not benefit from such long-term memory support, thus not producing an intrusion cost.

There was some evidence supporting the idea that without long-term memory support, TBF memory traces were not very long-lived: while Oberauer measured a stable intrusion cost until 5000 ms, I was unable to detect intrusions at a delay of 5200 ms (Experiment 2C – note, though, that performance did not change in a consistent manner across delays). Within Oberauer's model, this would indicate that the corresponding memory traces had decayed so that the TBF probe would no longer trigger the familiarity signal required to produce an intrusion cost. Furthermore, in contrast to Oberauer's verbal memory study, TBR items were negatively affected by an increase of delay. This could be due to the fact that without the support of pre-existing long-term memory traces, it should be quite hard to maintain information in memory over longer periods of time.

(b) Opposing the view that the intrusion cost is evidence for Oberauer's model

On the surface, Series 1 found consistent evidence for the idea that TBF material decays rapidly without long-term memory support: With single location probes, an intrusion cost was only found if participants had familiarised themselves with the material prior to testing.

However, combining these results with those from Series 2 and 3, it seems unlikely that prior learning produced intrusions because of the strengthening of long-term memory representations. Instead, an alternative explanation was proposed whereby prior learning may have altered perceptual strategies: Provided encoding and probe processing were similar, intrusions costs were obtained even with items lacking long-term memory support (Series 2 and 3).

The fact that an intrusion cost emerged even in the absence of any long-term memory trace slowing down the decay of the TBF material was a very important finding. To recap, Oberauer used the intrusion cost as evidence for his model in which working memory is embedded in long-term memory, and in which an item is available to varied degrees depending on its current functional state: If it is in the direct access region (where the TBR material is presumed to be held), then it is readily available. If it is in the activated subset of long-term memory (where the TBF material is presumably stored), it is no longer directly accessible, but can still indirectly affect performance. For example, in the case of the intrusion cost, the TBF material is thought to be held in the activated subset of long-term memory. Here, these traces do not decay immediately, because they are firmly anchored in long-term memory. The resilient activation of the TBF representations would trigger a familiarity signal slowing down participants' rejection of a TBF probe, because the signal forces them to consider whether this item may in fact be from the TBR set.

It has been difficult to consolidate the findings from the present studies with this interpretation. In Series 2 and 3, intrusion costs were found even with items that were not held in long-term memory. Evidence was also found suggesting that the familiarity underlying the intrusion cost may be driven by facilitated perceptual fluency, rather than the relative degree to which the information is held in long-term memory. Such results show that there is an alternative interpretation of the intrusion cost which does not rely on long-term memory involvement.

If this is the case, then it must be questioned whether it is at all possible to argue that the intrusion cost is evidence for Oberauer's model. Clearly, Oberauer's interpretation rests firmly on the assumption that the familiarity underlying the intrusion cost occurred because of resilient long-term memory activation of the TBF representations. The studies here show that this is not the only plausible explanation – participants may have also experienced feelings of familiarity because the repeated processing of the TBF item enhanced participants' perceptual fluency. In other words, the intrusion cost may not indicate where the TBF material is stored in memory. Instead, the actual reason why participants were familiar with the TBF probe may be because they had processed it before – the functional state of the material is stored in memory may be irrelevant for the relative familiarity of the item. This is highly problematic for the idea that the intrusion cost can be used as convincing evidence for Oberauer's model.

Because alternative theories exist that may account for the intrusion cost, Oberauer's model may not offer an appropriate explanation for the intrusion cost that occurred in this thesis. Indeed, his model might even be unable to account for the verbal intrusion cost observed in Oberauer's own studies. It is quite possible that, similarly to what was found here, the type of familiarity driving the verbal intrusion cost may also be based on perceptual fluency - although this is something that future research must explore in more detail.

(c) Oberauer's model: A conclusive view of memory?

As was discussed above, it is questionable whether the intrusion cost can in fact be regarded as evidence for Oberauer's model, as the familiarity driving the intrusion cost may have nothing to do with the functional state of the memory representation of the item. Although this does throw doubt on the notion that the intrusion cost can be used to demonstrate the validity of this model, it is not to say that Oberauer's model is inaccurate.

Indeed, one aspect that the model was able to explain was the finding that participants struggled to selectively encode TBF and TBR items if they were spatially confusable (Series 3). Such a finding indicated that participants grouped any items that were spatially linked – regardless of whether they were to-be-remembered or to-be-forgotten. This is in line with Oberauer's idea of memory involving a large network of interconnected traces, in which an activated trace passes on some of its activation to all closely related traces, making it difficult to selectively rehearse one trace whilst ignoring all its neighbouring traces.

However, one issue that the studies in this thesis point out is that the current version of Oberauer's model does not talk sufficiently about the processes involved in the creation of new long-term memory traces. The model is based on the assumption that the incoming information is already stored in long-term memory – but what happens to material that is new to the individual? Do we store all information in long-term memory, or only those items we consciously pay attention to? How is new material stored permanently in long-term memory? Because none of these issues have been addressed by the model, it has proven hard to use it as a reference point to analyse the data in this thesis – in fact, as already discussed above, the model may not be required at all to make sense of the intrusion cost.

Findings have been presented contributing to the increasing evidence that verbal and nonverbal memory share common processes – comparable to what previous research has shown in verbal memory (Oberauer, 2001), the experiments reported here also found an intrusion cost with nonverbal material. This is in line with Oberauer's model, because it does not explicitly argue for a functional segregation of verbal and nonverbal memory, and challenges models in which verbal and nonverbal memory are represented in separate modalities (e.g. Baddeley, 1999). All the same, there has thus far not been an explicit account of how verbal and nonverbal memory interact with one another in the Focus of Attention model, and this is another issue that may need to be addressed in future.

In summary, because the intrusion cost may be governed by factors other than long-term memory, Oberauer's model has been of limited use in the analysis of the results presented here. Results have certainly raised the question whether the intrusion cost can be exploited as evidence for the validity of the Focus of Attention model.

With regard to the model itself, a number of shortcomings have been identified above, but these should not be interpreted as a rejection of the model per se. Rather, it seems that various issues must be accommodated in the model first before it can be regarded as a conclusive and comprehensive view of memory. Such factors may include how new material is incorporated in long-term memory or how verbal and nonverbal material can be stored by one and the same system.

(5.6) Conclusions

In summary, the studies reported here indicate a number of factors that influence our ability to ignore no longer relevant information. These include the perceptual relationship between relevant and irrelevant material (it is easier to ignore locations that are clearly segregated from the TBR set), the congruence between encoding and retrieval processes (intrusions are more likely to occur if there are processing similarities between encoding and retrieval), the size of the TBR and TBF set (performance is only negatively affected by an increase in the amount of TBR information), and the delay between forget command and test (intrusions become less likely as the delay increases).

There was some preliminary evidence supporting the notion that the intrusion cost emerges as a consequence of familiarity signals triggered by resilient long-term memory traces corresponding the TBF material, although some reservations remain regarding this view. A competing interpretation was presented arguing that when stimuli are not represented by existing traces in memory, the familiarity signal producing the intrusion cost may not in fact be due to long-term memory processes, but due to the repeated processing of the no longer relevant material. Such an interpretation potentially reduces the applicability of Oberauer's Focus of Attention Model of memory, and it was argued that the intrusion cost may not actually represent convincing evidence for this model. Future research is required to clarify the nature of the familiarity signal that is needed to detect an intrusion cost.

Similarities between verbal and nonverbal forgetting processes were interpreted as support for unitary memory models. It is important to note that, up until this point, the literature has for the most part focused on forgetting in verbal memory, with very little insight into processes involved in nonverbal forgetting. More research is therefore needed to explore to what extent forgetting processes are compatible across modalities, and how such processes can be successfully integrated into a theoretical framework.

APPENDICES

(1A) Experiment 1A: Response times (between learning and control condition)

Descriptive Statistics

	CONDITIO	Mean	Std. Deviation	N
RA1	control	971.8696	334.40168	23
	practice	1044.8478	305.50816	23
	Total	1008.3587	318.84377	46
FA1	control	969.4565	260.90367	23
	practice	993.3043	298.74734	23
	Total	981.3804	277.59265	46
DA1	control	1031.0217	269.94185	23
	practice	1030.0217	329.08339	23
	Total	1030.5217	297.60638	46
RA2	control	876.4565	257.79012	23
	practice	906.8478	262.83431	23
	Total	891.6522	257.87376	46
FA2	control	794.2391	273.94977	23
	practice	777.1304	238.00646	23
	Total	785.6848	253.88835	46
DA2	control	754.0000	235.63623	23
	practice	795.3043	284.04920	23
	Total	774.6522	258.89526	46

RA1 = TBR probes in the first 30 trials
RA2 = TBR probes in the last 30 trials
FA1 = TBF probes in the first 30 trials
FA2 = TBF probes in the last 30 trials
DA1 = Control probes in the first 30 trials
DA2 = Control probes in the last 30 trials

Estimates

Measure: MEASURE_1

CONDITIO	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
control	899.507	51.732	795.248	1003.767
practice	924.576	51.732	820.316	1028.836

Univariate Tests

Measure: MEASURE_1

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	7227.138	1	7227.138	.117	.733
Error	2708351	44	61553.432		

The F tests the effect of CONDITIO. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Comparison of response times in learning (practice) and control condition.

Estimates

Measure: MEASURE_1

SECTION	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	1006.754	42.035	922.038	1091.470
2	817.330	36.724	743.317	891.343

Comparison of response times between first and last 30 trials (learning and control condition, as well as probe types combined).

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	950.005	40.071	869.248	1030.763
2	883.533	35.690	811.605	955.461
3	902.587	37.820	826.365	978.809

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	66.473*	19.310	.001	27.555	105.390
	3	47.418*	19.323	.018	8.476	86.361
2	1	-66.473*	19.310	.001	-105.390	-27.555
	3	-19.054	11.837	.115	-42.910	4.801
3	1	-47.418*	19.323	.018	-86.361	-8.476
	2	19.054	11.837	.115	-4.801	42.910

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of response times between probe types (condition and first/last 30 trials combined).

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
SECTION	1.000	.000	0	.	1.000	1.000	1.000
PROBE	.724	13.915	2	.001	.783	.826	.500
SECTION * PROBE	.841	7.453	2	.024	.863	.915	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept+CONDITIO

Within Subjects Design: SECTION+PROBE+SECTION*PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SECTION	Sphericity Assumed	2475817.899	1	2475817.899	40.832	.000
	Greenhouse-Geisser	2475817.899	1.000	2475817.899	40.832	.000
	Huynh-Feldt	2475817.899	1.000	2475817.899	40.832	.000
	Lower-bound	2475817.899	1.000	2475817.899	40.832	.000
SECTION * CONDITIO	Sphericity Assumed	3259.610	1	3259.610	.054	.818
	Greenhouse-Geisser	3259.610	1.000	3259.610	.054	.818
	Huynh-Feldt	3259.610	1.000	3259.610	.054	.818
	Lower-bound	3259.610	1.000	3259.610	.054	.818
Error(SECTION)	Sphericity Assumed	2667885.116	44	60633.753		
	Greenhouse-Geisser	2667885.116	44.000	60633.753		
	Huynh-Feldt	2667885.116	44.000	60633.753		
	Lower-bound	2667885.116	44.000	60633.753		
PROBE	Sphericity Assumed	215593.317	2	107796.659	7.931	.001
	Greenhouse-Geisser	215593.317	1.567	137598.868	7.931	.002
	Huynh-Feldt	215593.317	1.651	130552.228	7.931	.002
	Lower-bound	215593.317	1.000	215593.317	7.931	.007
PROBE * CONDITIO	Sphericity Assumed	27679.132	2	13839.566	1.018	.365
	Greenhouse-Geisser	27679.132	1.567	17665.748	1.018	.350
	Huynh-Feldt	27679.132	1.651	16761.059	1.018	.354
	Lower-bound	27679.132	1.000	27679.132	1.018	.318
Error(PROBE)	Sphericity Assumed	1196013.467	88	13591.062		
	Greenhouse-Geisser	1196013.467	68.940	17348.541		
	Huynh-Feldt	1196013.467	72.661	16460.097		
	Lower-bound	1196013.467	44.000	27182.124		
SECTION * PROBE	Sphericity Assumed	224070.103	2	112035.052	13.657	.000
	Greenhouse-Geisser	224070.103	1.725	129864.763	13.657	.000
	Huynh-Feldt	224070.103	1.830	122432.531	13.657	.000
	Lower-bound	224070.103	1.000	224070.103	13.657	.001
SECTION * PROBE * CONDITIO	Sphericity Assumed	27104.665	2	13552.332	1.652	.198
	Greenhouse-Geisser	27104.665	1.725	15709.105	1.652	.201
	Huynh-Feldt	27104.665	1.830	14810.065	1.652	.200
	Lower-bound	27104.665	1.000	27104.665	1.652	.205
Error(SECTION*PROBE)	Sphericity Assumed	721896.982	88	8203.375		
	Greenhouse-Geisser	721896.982	75.918	9508.893		
	Huynh-Feldt	721896.982	80.527	8964.694		
	Lower-bound	721896.982	44.000	16406.750		

(1b) Experiment 1A: Response times in the learning condition

First 30 trials

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.914	1.897	2	.387	.920	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	32389.442	2	16194.721	1.829	.173
	Greenhouse-Geisser	32389.442	1.841	17593.805	1.829	.176
	Huynh-Feldt	32389.442	2.000	16194.721	1.829	.173
	Lower-bound	32389.442	1.000	32389.442	1.829	.190
Error(PROBE)	Sphericity Assumed	389547.225	44	8853.346		
	Greenhouse-Geisser	389547.225	40.501	9618.199		
	Huynh-Feldt	389547.225	44.000	8853.346		
	Lower-bound	389547.225	22.000	17706.692		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	1044.848	63.703	912.736	1176.959
2	993.304	62.293	864.116	1122.492
3	1030.022	68.619	887.715	1172.328

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	51.543	29.079	.090	-8.762	111.849
	3	14.826	30.276	.629	-47.963	77.615
2	1	-51.543	29.079	.090	-111.849	8.762
	3	-36.717	23.395	.131	-85.236	11.801
3	1	-14.826	30.276	.629	-77.615	47.963
	2	36.717	23.395	.131	-11.801	85.236

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

Last 30 trials

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effec	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.835	3.790	2	.150	.858	.924	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed i Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	226924.442	2	113462.221	18.816	.000
	Greenhouse-Geisser	226924.442	1.717	132196.873	18.816	.000
	Huynh-Feldt	226924.442	1.848	122803.813	18.816	.000
	Lower-bound	226924.442	1.000	226924.442	18.816	.000
Error(PROBE)	Sphericity Assumed	265320.225	44	6030.005		
	Greenhouse-Geisser	265320.225	37.764	7025.667		
	Huynh-Feldt	265320.225	40.653	6526.469		
	Lower-bound	265320.225	22.000	12060.010		

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
PROBE	Mean	Std. Error	Lower Bound	Upper Bound
1	906.848	54.805	793.190	1020.506
2	777.130	49.628	674.209	880.052
3	795.304	59.228	672.472	918.136

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	129.717*	26.164	.000	75.457	183.978
	3	111.543*	23.789	.000	62.208	160.879
2	1	-129.717*	26.164	.000	-183.978	-75.457
	3	-18.174	17.961	.323	-55.422	19.074
3	1	-111.543*	23.789	.000	-160.879	-62.208
	2	18.174	17.961	.323	-19.074	55.422

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(1c) Experiment 1A: Response times in the control condition

First 30 trials

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.561	12.146	2	.002	.695	.727	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	55928.935	2	27964.467	1.462	.243
	Greenhouse-Geisser	55928.935	1.390	40246.481	1.462	.244
	Huynh-Feldt	55928.935	1.454	38472.305	1.462	.244
	Lower-bound	55928.935	1.000	55928.935	1.462	.239
Error(PROBE)	Sphericity Assumed	841791.732	44	19131.630		
	Greenhouse-Geisser	841791.732	30.573	27534.256		
	Huynh-Feldt	841791.732	31.982	26320.470		
	Lower-bound	841791.732	22.000	38263.261		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	971.870	69.728	827.263	1116.476
2	969.457	54.402	856.633	1082.280
3	1031.022	56.287	914.290	1147.753

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	2.413	46.101	.959	-93.194	98.020
	3	-59.152	47.957	.230	-158.609	40.305
2	1	-2.413	46.101	.959	-98.020	93.194
	3	-61.565*	23.785	.017	-110.892	-12.238
3	1	59.152	47.957	.230	-40.305	158.609
	2	61.565*	23.785	.017	12.238	110.892

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

Last 30 trials

Mauchly's Test of Sphericity

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.829	3.938	2	.140	.854	.919	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed i Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	179272.630	2	89636.315	9.365	.000
	Greenhouse-Geisser	179272.630	1.708	104961.921	9.365	.001
	Huynh-Feldt	179272.630	1.837	97571.452	9.365	.001
	Lower-bound	179272.630	1.000	179272.630	9.365	.006
Error(PROBE)	Sphericity Assumed	421141.703	44	9571.402		
	Greenhouse-Geisser	421141.703	37.576	11207.877		
	Huynh-Feldt	421141.703	40.422	10418.720		
	Lower-bound	421141.703	22.000	19142.805		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	876.478	53.746	765.016	987.941
2	794.239	57.122	675.774	912.704
3	754.000	49.134	652.103	855.897

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	82.239*	33.923	.024	11.887	152.591
	3	122.478*	28.035	.000	64.336	180.620
2	1	-82.239*	33.923	.024	-152.591	-11.887
	3	40.239	23.667	.103	-8.843	89.321
3	1	-122.478*	28.035	.000	-180.620	-64.336
	2	-40.239	23.667	.103	-89.321	8.843

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(1d) Experiment 1A: Accuracy data (between learning and control condition)

Descriptive Statistics

	COND	Mean	Std. Deviation	N
RA1	no practice	73.5870	13.24649	23
	practice	78.6957	12.54242	23
	Total	76.1413	13.01395	46
FA1	no practice	85.0261	11.73314	23
	practice	91.7391	9.84063	23
	Total	88.3826	11.23224	46
DA1	no practice	76.5217	17.21751	23
	practice	79.8565	17.33417	23
	Total	78.1891	17.16589	46
RA2	no practice	73.0435	16.07787	23
	practice	76.5217	18.49046	23
	Total	74.7826	17.22261	46
FA2	no practice	94.2043	9.15396	23
	practice	95.6522	7.87752	23
	Total	94.9283	8.47587	46
DA2	no practice	95.6522	6.62371	23
	practice	93.9130	11.17592	23
	Total	94.7826	9.12606	46

RA1 = TBR probes in the first 30 trials
RA2 = TBR probes in the last 30 trials
FA1 = TBF probes in the first 30 trials
FA2 = TBF probes in the last 30 trials
DA1 = Control probes in the first 30 trials
DA2 = Control probes in the last 30 trials

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
COND	Mean	Std. Error	Lower Bound	Upper Bound
no practice	83.006	1.439	80.105	85.906
practice	86.063	1.439	83.162	88.964

Univariate Tests

Measure: MEASURE_1

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	107.488	1	107.488	2.256	.140
Error	2096.353	44	47.644		

The F tests the effect of COND. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Comparison of accuracy in learning (practice) and control condition.

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
SECTION	Mean	Std. Error	Lower Bound	Upper Bound
1	80.904	1.256	78.374	83.435
2	88.164	1.130	85.886	90.443

Comparison of accuracy between first and last 30 trials (learning and control condition, as well as probe types combined).

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	75.462	1.844	71.746	79.178
2	91.655	1.111	89.416	93.894
3	86.486	1.584	83.294	89.678

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1	2	-16.193*	1.967	.000	-20.157	-12.230
	3	-11.024*	2.405	.000	-15.870	-6.178
2	1	16.193*	1.967	.000	12.230	20.157
	3	5.170*	1.566	.002	2.013	8.326
3	1	11.024*	2.405	.000	6.178	15.870
	2	-5.170*	1.566	.002	-8.326	-2.013

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of accuracy between probe types (condition and first/last 30 trials combined).

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Epsilon[a] Huynh-Feldt	Epsilon[a] Lower-bound
SECTION	1.000	.000	0	.	1.000	1.000	1.000
PROBE	.771	11.160	2	.004	.814	.860	.500
SECTION * PROBE	.822	8.407	2	.015	.849	.900	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept+COND

Within Subjects Design: SECTION+PROBE+SECTION*PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SECTION	Sphericity Assumed	3636.970	1	3636.970	33.648	.000
	Greenhouse-Geisser	3636.970	1.000	3636.970	33.648	.000
	Huynh-Feldt	3636.970	1.000	3636.970	33.648	.000
	Lower-bound	3636.970	1.000	3636.970	33.648	.000
SECTION * COND	Sphericity Assumed	274.602	1	274.602	2.541	.118
	Greenhouse-Geisser	274.602	1.000	274.602	2.541	.118
	Huynh-Feldt	274.602	1.000	274.602	2.541	.118
	Lower-bound	274.602	1.000	274.602	2.541	.118
Error(SECTION)	Sphericity Assumed	4755.850	44	108.088		
	Greenhouse-Geisser	4755.850	44.000	108.088		
	Huynh-Feldt	4755.850	44.000	108.088		
	Lower-bound	4755.850	44.000	108.088		
PROBE	Sphericity Assumed	12588.047	2	6294.024	33.913	.000
	Greenhouse-Geisser	12588.047	1.628	7732.802	33.913	.000
	Huynh-Feldt	12588.047	1.720	7318.404	33.913	.000
	Lower-bound	12588.047	1.000	12588.047	33.913	.000
PROBE * COND	Sphericity Assumed	176.644	2	88.322	.476	.623
	Greenhouse-Geisser	176.644	1.628	108.512	.476	.584
	Huynh-Feldt	176.644	1.720	102.697	.476	.594
	Lower-bound	176.644	1.000	176.644	.476	.494
Error(PROBE)	Sphericity Assumed	16332.296	88	185.594		
	Greenhouse-Geisser	16332.296	71.627	228.020		
	Huynh-Feldt	16332.296	75.682	215.801		
	Lower-bound	16332.296	44.000	371.189		
SECTION * PROBE	Sphericity Assumed	3723.839	2	1861.919	13.567	.000
	Greenhouse-Geisser	3723.839	1.698	2192.554	13.567	.000
	Huynh-Feldt	3723.839	1.800	2069.245	13.567	.000
	Lower-bound	3723.839	1.000	3723.839	13.567	.001
SECTION * PROBE * COND	Sphericity Assumed	48.119	2	24.060	.175	.839
	Greenhouse-Geisser	48.119	1.698	28.332	.175	.804
	Huynh-Feldt	48.119	1.800	26.739	.175	.817
	Lower-bound	48.119	1.000	48.119	.175	.677
Error(SECTION*PROBE	Sphericity Assumed	12076.635	88	137.234		
	Greenhouse-Geisser	12076.635	74.730	161.604		
	Huynh-Feldt	12076.635	79.183	152.516		
	Lower-bound	12076.635	44.000	274.469		

(1e) Experiment 1A: Accuracy in the learning condition

First 30 trials

Mauchly's Test of Sphericity

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effec	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.573	11.682	2	.003	.701	.734	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed i Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	2397.185	2	1198.593	6.658	.003
	Greenhouse-Geisser	2397.185	1.402	1710.000	6.658	.008
	Huynh-Feldt	2397.185	1.468	1632.702	6.658	.008
	Lower-bound	2397.185	1.000	2397.185	6.658	.017
Error(PROBE)	Sphericity Assumed	7921.408	44	180.032		
	Greenhouse-Geisser	7921.408	30.841	256.847		
	Huynh-Feldt	7921.408	32.301	245.237		
	Lower-bound	7921.408	22.000	360.064		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	78.696	2.615	73.272	84.119
2	91.739	2.052	87.484	95.995
3	79.857	3.614	72.361	87.352

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1	2	-13.043*	2.699	.000	-18.642	-7.445
	3	-1.161	4.993	.818	-11.515	9.194
2	1	13.043*	2.699	.000	7.445	18.642
	3	11.883*	3.841	.005	3.918	19.847
3	1	1.161	4.993	.818	-9.194	11.515
	2	-11.883*	3.841	.005	-19.847	-3.918

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

Last 30 trials

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Epsilon[a] Huynh-Feldt	Epsilon[a] Lower-bound
PROBE	.655	8.885	2	.012	.744	.785	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	5147.826	2	2573.913	15.334	.000
	Greenhouse-Geisser	5147.826	1.487	3461.854	15.334	.000
	Huynh-Feldt	5147.826	1.570	3279.284	15.334	.000
	Lower-bound	5147.826	1.000	5147.826	15.334	.001
Error(PROBE)	Sphericity Assumed	7385.507	44	167.852		
	Greenhouse-Geisser	7385.507	32.714	225.758		
	Huynh-Feldt	7385.507	34.536	213.852		
	Lower-bound	7385.507	22.000	335.705		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	76.522	3.856	68.526	84.518
2	95.652	1.643	92.246	99.059
3	93.913	2.330	89.080	98.746

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-19.130*	4.166	.000	-27.771	-10.490
	3	-17.391*	4.499	.001	-26.722	-8.060
2	1	19.130*	4.166	.000	10.490	27.771
	3	1.739	2.487	.492	-3.419	6.897
3	1	17.391*	4.499	.001	8.060	26.722
	2	-1.739	2.487	.492	-6.897	3.419

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(1f) Experiment 1A: Accuracy in the control condition

First 30 trials

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.593	10.979	2	.004	.711	.746	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1623.728	2	811.864	4.401	.018
	Greenhouse-Geisser	1623.728	1.421	1142.406	4.401	.032
	Huynh-Feldt	1623.728	1.491	1088.749	4.401	.030
	Lower-bound	1623.728	1.000	1623.728	4.401	.048
Error(PROBE)	Sphericity Assumed	8117.226	44	184.482		
	Greenhouse-Geisser	8117.226	31.269	259.593		
	Huynh-Feldt	8117.226	32.810	247.400		
	Lower-bound	8117.226	22.000	368.965		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	73.587	2.762	67.859	79.315
2	85.026	2.447	79.952	90.100
3	76.522	3.590	69.076	83.967

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-11.439*	3.556	.004	-18.813	-4.065
	3	-2.935	5.109	.572	-13.530	7.661
2	1	11.439*	3.556	.004	4.065	18.813
	3	8.504*	3.063	.011	2.153	14.856
3	1	2.935	5.109	.572	-7.661	13.530
	2	-8.504*	3.063	.011	-14.856	-2.153

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

Last 30 trials

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.372	20.775	2	.000	.614	.632	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	7367.910	2	3683.955	32.518	.000
	Greenhouse-Geisser	7367.910	1.228	5998.089	32.518	.000
	Huynh-Feldt	7367.910	1.264	5829.637	32.518	.000
	Lower-bound	7367.910	1.000	7367.910	32.518	.000
Error(PROBE)	Sphericity Assumed	4984.790	44	113.291		
	Greenhouse-Geisser	4984.790	27.024	184.456		
	Huynh-Feldt	4984.790	27.805	179.276		
	Lower-bound	4984.790	22.000	226.581		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	73.043	3.352	66.091	79.996
2	94.204	1.909	90.246	98.163
3	95.652	1.381	92.788	98.516

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-21.161*	4.178	.000	-29.825	-12.497
	3	-22.609*	2.756	.000	-28.324	-16.893
2	1	21.161*	4.178	.000	12.497	29.825
	3	-1.448	2.123	.502	-5.850	2.954
3	1	22.609*	2.756	.000	16.893	28.324
	2	1.448	2.123	.502	-2.954	5.850

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(2a) Experiment 1B: Response times data (between learning and control condition)

Descriptive Statistics

	CONDITIO	Mean	Std. Deviation	N
TBR	control	1082.7000	330.83279	25
	practice	1140.0800	298.17140	25
	Total	1111.3900	313.04013	50
TBF	control	1033.3800	333.04690	25
	practice	1148.9000	380.29024	25
	Total	1091.1400	358.56268	50
CONTROL	control	1060.1400	345.72395	25
	practice	1153.4000	449.99194	25
	Total	1106.7700	399.92716	50

Estimates

Measure: MEASURE_1

CONDITIO	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
control	1058.740	66.805	924.420	1193.060
practice	1147.460	66.805	1013.140	1281.780

Pairwise Comparisons

Measure: MEASURE_1

(I) CONDITIO	(J) CONDITIO	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
control	practice	-88.720	94.476	.352	-278.677	101.237
practice	control	88.720	94.476	.352	-101.237	278.677

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Measure: MEASURE_1

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	98390.480	1	98390.480	.882	.352
Error	5355441	48	111571.683		

The F tests the effect of CONDITIO. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Comparison of response times in learning (practice) and control condition.

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1111.390	44.537	1021.842	1200.938
2	1091.140	50.551	989.500	1192.780
3	1106.770	56.747	992.673	1220.867

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1	2	20.250	33.378	.547	-46.861	87.361
	3	4.620	30.631	.881	-56.967	66.207
2	1	-20.250	33.378	.547	-87.361	46.861
	3	-15.630	33.797	.646	-83.584	52.324
3	1	-4.620	30.631	.881	-66.207	56.967
	2	15.630	33.797	.646	-52.324	83.584

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of response times between probe types (conditions combined).1 = TBR probe, 2 = TBF probe, 3 = Control probe

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.986	.680	2	.712	.986	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+CONDITIO
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	11261.730	2	5630.865	.212	.810
	Greenhouse-Geisser	11261.730	1.972	5711.792	.212	.807
	Huynh-Feldt	11261.730	2.000	5630.865	.212	.810
	Lower-bound	11261.730	1.000	11261.730	.212	.648
PROBE * CONDITIO	Sphericity Assumed	21513.090	2	10756.545	.404	.669
	Greenhouse-Geisser	21513.090	1.972	10911.139	.404	.666
	Huynh-Feldt	21513.090	2.000	10756.545	.404	.669
	Lower-bound	21513.090	1.000	21513.090	.404	.528
Error(PROBE)	Sphericity Assumed	2555642.847	96	26621.280		
	Greenhouse-Geisser	2555642.847	94.640	27003.884		
	Huynh-Feldt	2555642.847	96.000	26621.280		
	Lower-bound	2555642.847	48.000	53242.559		

(2b) Experiment 1B: Response times data in learning condition

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.954	1.083	2	.582	.956	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	2295.540	2	1147.770	.039	.962
	Greenhouse-Geisser	2295.540	1.912	1200.554	.039	.957
	Huynh-Feldt	2295.540	2.000	1147.770	.039	.962
	Lower-bound	2295.540	1.000	2295.540	.039	.845
Error(PROBE)	Sphericity Assumed	1413812.127	48	29454.419		
	Greenhouse-Geisser	1413812.127	45.890	30808.977		
	Huynh-Feldt	1413812.127	48.000	29454.419		
	Lower-bound	1413812.127	24.000	58908.839		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1140.080	59.634	1017.001	1263.159
2	1148.900	76.058	991.924	1305.876
3	1153.400	89.998	967.652	1339.148

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-8.820	46.808	.852	-105.428	87.788
	3	-13.320	45.005	.770	-106.206	79.566
2	1	8.820	46.808	.852	-87.788	105.428
	3	-4.500	53.409	.934	-114.731	105.731
3	1	13.320	45.005	.770	-79.566	106.206
	2	4.500	53.409	.934	-105.731	114.731

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(2c) Experiment 1B: Response times data in control condition

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.964	.849	2	.654	.965	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	30479.280	2	15239.640	.641	.531
	Greenhouse-Geisser	30479.280	1.930	15791.910	.641	.526
	Huynh-Feldt	30479.280	2.000	15239.640	.641	.531
	Lower-bound	30479.280	1.000	30479.280	.641	.431
Error(PROBE)	Sphericity Assumed	1141830.720	48	23788.140		
	Greenhouse-Geisser	1141830.720	46.321	24650.200		
	Huynh-Feldt	1141830.720	48.000	23788.140		
	Lower-bound	1141830.720	24.000	47576.280		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	1082.700	66.167	946.139	1219.261
2	1033.380	66.609	895.905	1170.855
3	1060.140	69.145	917.432	1202.848

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	49.320	47.595	.310	-48.911	147.551
	3	22.560	41.563	.592	-63.221	108.341
2	1	-49.320	47.595	.310	-147.551	48.911
	3	-26.760	41.430	.524	-112.267	58.747
3	1	-22.560	41.563	.592	-108.341	63.221
	2	26.760	41.430	.524	-58.747	112.267

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(2d) Experiment 1B: Accuracy data (between learning and control condition)

Descriptive Statistics

	CONDITIO	Mean	Std. Deviation	N
TBR	control	74.3920	15.36229	25
	practice	75.9960	15.99551	25
	Total	75.1940	15.54238	50
TBF	control	81.5960	13.64073	25
	practice	87.0640	10.81337	25
	Total	84.3300	12.49139	50
CONTROL	control	80.2640	15.69036	25
	practice	80.5480	15.12741	25
	Total	80.4060	15.25406	50

Estimates

Measure: MEASURE_1

CONDITIO	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
control	78.751	2.056	74.618	82.884
practice	81.203	2.056	77.070	85.336

Univariate Tests

Measure: MEASURE_1

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	75.154	1	75.154	.711	.403
Error	5070.669	48	105.639		

The F tests the effect of CONDITIO. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Comparison of accuracy in learning (practice) and control condition.

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	75.194	2.218	70.735	79.653
2	84.330	1.741	80.830	87.830
3	80.406	2.180	76.024	84.788

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-9.136*	2.079	.000	-13.316	-4.956
	3	-5.212	3.139	.103	-11.524	1.100
2	1	9.136*	2.079	.000	4.956	13.316
	3	3.924	2.215	.083	-.529	8.377
3	1	5.212	3.139	.103	-1.100	11.524
	2	-3.924	2.215	.083	-8.377	.529

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of accuracy between probe types (conditions combined). 1 = TBR probe, 2 = TBF probe, 3 = Control probe.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.695	17.087	2	.000	.766	.803	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+CONDITIO
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	2100.487	2	1050.243	6.605	.002
	Greenhouse-Geisser	2100.487	1.533	1370.352	6.605	.005
	Huynh-Feldt	2100.487	1.606	1307.652	6.605	.004
	Lower-bound	2100.487	1.000	2100.487	6.605	.013
PROBE * CONDITIO	Sphericity Assumed	181.445	2	90.722	.571	.567
	Greenhouse-Geisser	181.445	1.533	118.374	.571	.523
	Huynh-Feldt	181.445	1.606	112.958	.571	.531
	Lower-bound	181.445	1.000	181.445	.571	.454
Error(PROBE)	Sphericity Assumed	15265.128	96	159.012		
	Greenhouse-Geisser	15265.128	73.575	207.478		
	Huynh-Feldt	15265.128	77.103	197.985		
	Lower-bound	15265.128	48.000	318.024		

(2e) Experiment 1B: Accuracy data in learning condition

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.744	6.801	2	.033	.796	.844	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1547.330	2	773.665	4.153	.022
	Greenhouse-Geisser	1547.330	1.592	971.700	4.153	.031
	Huynh-Feldt	1547.330	1.687	917.008	4.153	.029
	Lower-bound	1547.330	1.000	1547.330	4.153	.053
Error(PROBE)	Sphericity Assumed	8941.770	48	186.287		
	Greenhouse-Geisser	8941.770	38.217	233.971		
	Huynh-Feldt	8941.770	40.497	220.802		
	Lower-bound	8941.770	24.000	372.574		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	75.996	3.199	69.393	82.599
2	87.064	2.163	82.600	91.528
3	80.548	3.025	74.304	86.792

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-11.068*	3.167	.002	-17.605	-4.531
	3	-4.552	4.725	.345	-14.303	5.199
2	1	11.068*	3.167	.002	4.531	17.605
	3	6.516	3.515	.076	-.738	13.770
3	1	4.552	4.725	.345	-5.199	14.303
	2	-6.516	3.515	.076	-13.770	.738

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(2f) Experiment 1B: Accuracy data in control condition

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,612	11,279	2	,004	,721	,754	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	734,602	2	367,301	2,788	,072
	Greenhouse-Geisser	734,602	1,441	509,676	2,788	,091
	Huynh-Feldt	734,602	1,509	486,932	2,788	,088
	Lower-bound	734,602	1,000	734,602	2,788	,108
Error(PROBE)	Sphericity Assumed	6323,358	48	131,737		
	Greenhouse-Geisser	6323,358	34,591	182,801		
	Huynh-Feldt	6323,358	36,207	174,644		
	Lower-bound	6323,358	24,000	263,473		

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	74,392	3,072	68,051	80,733
2	81,596	2,728	75,965	87,227
3	80,264	3,138	73,787	86,741

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-7,204*	2,693	,013	-12,762	-1,646
	3	-5,872	4,135	,168	-14,407	2,663
2	1	7,204*	2,693	,013	1,646	12,762
	3	1,332	2,695	,626	-4,231	6,895
3	1	5,872	4,135	,168	-2,663	14,407
	2	-1,332	2,695	,626	-6,895	4,231

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(3a) Experiment 1C: Response times data (between control and learning condition)

Descriptive Statistics

	CONDITIO	Mean	Std. Deviation	N
TBR	no practice	1064.3000	317.42004	20
	practice	1029.4250	156.62193	20
	Total	1046.8625	247.68647	40
TBF	no practice	962.0750	281.58430	20
	practice	935.8750	148.62580	20
	Total	948.9750	222.63411	40
CONTROL	no practice	964.4250	254.04057	20
	practice	883.8000	155.46504	20
	Total	924.1125	211.85492	40

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
CONDITIO	Mean	Std. Error	Lower Bound	Upper Bound
no practice	996.933	42.278	911.345	1082.522
practice	949.700	42.278	864.112	1035.288

Univariate Tests

Measure: MEASURE_1

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	22309.878	1	22309.878	.624	.434
Error	1358477	38	35749.390		

The F tests the effect of CONDITIO. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Difference between control (no practice) and learning (practice) condition irrespective of probe type.

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
PROBE	Mean	Std. Error	Lower Bound	Upper Bound
1	1046.863	39.574	966.750	1126.975
2	948.975	35.598	876.910	1021.040
3	924.113	33.299	856.702	991.523

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	97.887*	37.013	.012	22.958	172.817
	3	122.750*	39.275	.003	43.241	202.259
2	1	-97.887*	37.013	.012	-172.817	-22.958
	3	24.862	29.500	.405	-34.858	84.583
3	1	-122.750*	39.275	.003	-202.259	-43.241
	2	-24.862	29.500	.405	-84.583	34.858

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of response times between probe types (conditions combined). 1 = TBR probe, 2 = TBF probe, 3 = Control probe

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.898	3.990	2	.136	.907	.975	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+CONDITIO
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	336902.254	2	168451.127	6.680	.002
	Greenhouse-Geisser	336902.254	1.814	185673.051	6.680	.003
	Huynh-Feldt	336902.254	1.950	172726.479	6.680	.002
	Lower-bound	336902.254	1.000	336902.254	6.680	.014
PROBE * CONDITIO	Sphericity Assumed	17101.329	2	8550.665	.339	.714
	Greenhouse-Geisser	17101.329	1.814	9424.858	.339	.693
	Huynh-Feldt	17101.329	1.950	8767.684	.339	.708
	Lower-bound	17101.329	1.000	17101.329	.339	.564
Error(PROBE)	Sphericity Assumed	1916623.250	76	25218.727		
	Greenhouse-Geisser	1916623.250	68.951	27797.012		
	Huynh-Feldt	1916623.250	74.119	25858.788		
	Lower-bound	1916623.250	38.000	50437.454		

(3b) Experiment 1C: Response times data in control condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	1064.3000	317.42004	20
TBF	962.0750	281.58430	20
CONTROL	964.4250	254.04057	20

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.912	1.661	2	.436	.919	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	136203.258	2	68101.629	1.718	.193
	Greenhouse-Geisser	136203.258	1.838	74103.456	1.718	.196
	Huynh-Feldt	136203.258	2.000	68101.629	1.718	.193
	Lower-bound	136203.258	1.000	136203.258	1.718	.206
Error(PROBE)	Sphericity Assumed	1506155.742	38	39635.677		
	Greenhouse-Geisser	1506155.742	34.922	43128.787		
	Huynh-Feldt	1506155.742	38.000	39635.677		
	Lower-bound	1506155.742	19.000	79271.355		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]. Lower Bound	Upper Bound
1	2	102.225	61.786	.114	-27.095	231.545
	3	99.875	71.047	.176	-48.829	248.579
2	1	-102.225	61.786	.114	-231.545	27.095
	3	-2.350	55.004	.966	-117.475	112.775
3	1	-99.875	71.047	.176	-248.579	48.829
	2	2.350	55.004	.966	-112.775	117.475

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(3c) Experiment 1C: Response times data in learning condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	1029.4250	156.62193	20
TBF	935.8750	148.62580	20
CONTROL	883.8000	155.46504	20

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.582	9.732	2	.008	.705	.745	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	217800.325	2	108900.163	10.082	.000
	Greenhouse-Geisser	217800.325	1.411	154382.296	10.082	.002
	Huynh-Feldt	217800.325	1.490	146131.316	10.082	.001
	Lower-bound	217800.325	1.000	217800.325	10.082	.005
Error(PROBE)	Sphericity Assumed	410467.508	38	10801.777		
	Greenhouse-Geisser	410467.508	26.805	15313.137		
	Huynh-Feldt	410467.508	28.318	14494.724		
	Lower-bound	410467.508	19.000	21603.553		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	93.550*	40.773	.033	8.211	178.889
	3	145.625*	33.504	.000	75.501	215.749
2	1	-93.550*	40.773	.033	-178.889	-8.211
	3	52.075*	21.344	.025	7.401	96.749
3	1	-145.625*	33.504	.000	-215.749	-75.501
	2	-52.075*	21.344	.025	-96.749	-7.401

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(3d) Experiment 1C: Accuracy data (between control and learning condition)

Descriptive Statistics

	CONDITIO	Mean	Std. Deviation	N
TBR	control	69.9950	10.02515	20
	practice	69.6750	14.59534	20
	Total	69.8350	12.36004	40
TBF	control	69.3400	15.05112	20
	practice	77.6650	13.54972	20
	Total	73.5025	14.75053	40
CONTROL	control	75.6750	11.70123	20
	practice	81.6600	12.76786	20
	Total	78.6675	12.46226	40

Estimates

Measure: MEASURE_1

CONDITIO	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
control	71.670	2.043	67.533	75.807
practice	76.333	2.043	72.197	80.470

Univariate Tests

Measure: MEASURE_1

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	217.467	1	217.467	2.604	.115
Error	3173.562	38	83.515		

The F tests the effect of CONDITIO. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Difference between control (no practice) and learning (practice) condition irrespective of probe type.

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	69.835	1.980	65.827	73.843
2	73.503	2.264	68.919	78.086
3	78.668	1.936	74.748	82.587

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1	2	-3.668	2.553	.159	-8.837	1.502
	3	-8.833*	2.743	.003	-14.386	-3.279
2	1	3.668	2.553	.159	-1.502	8.837
	3	-5.165*	2.355	.035	-9.933	-.397
3	1	8.833*	2.743	.003	3.279	14.386
	2	5.165*	2.355	.035	.397	9.933

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of accuracy between probe types (conditions combined). 1 = TBR probe, 2 = TBF probe, 3 = Control probe

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Epsilon[a] Huynh-Feldt	Epsilon[a] Lower-bound
PROBE	.969	1.150	2	.563	.970	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept+CONDITIO
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1575.211	2	787.606	6.029	.004
	Greenhouse-Geisser	1575.211	1.941	811.714	6.029	.004
	Huynh-Feldt	1575.211	2.000	787.606	6.029	.004
	Lower-bound	1575.211	1.000	1575.211	6.029	.019
PROBE * CONDITIO	Sphericity Assumed	399.882	2	199.941	1.531	.223
	Greenhouse-Geisser	399.882	1.941	206.061	1.531	.224
	Huynh-Feldt	399.882	2.000	199.941	1.531	.223
	Lower-bound	399.882	1.000	399.882	1.531	.224
Error(PROBE)	Sphericity Assumed	9927.640	76	130.627		
	Greenhouse-Geisser	9927.640	73.743	134.625		
	Huynh-Feldt	9927.640	76.000	130.627		
	Lower-bound	9927.640	38.000	261.254		

(3e) Experiment 1C: Accuracy data in control condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	69.9950	10.02515	20
TBF	69.3400	15.05112	20
CONTROL	75.6750	11.70123	20

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.896	1.974	2	.373	.906	.996	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	485.491	2	242.746	2.040	.144
	Greenhouse-Geisser	485.491	1.812	267.958	2.040	.149
	Huynh-Feldt	485.491	1.992	243.738	2.040	.144
	Lower-bound	485.491	1.000	485.491	2.040	.169
Error(PROBE)	Sphericity Assumed	4521.796	38	118.995		
	Greenhouse-Geisser	4521.796	34.425	131.354		
	Huynh-Feldt	4521.796	37.845	119.481		
	Lower-bound	4521.796	19.000	237.989		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	.655	2.859	.821	-5.329	6.639
	3	-5.680	3.814	.153	-13.663	2.303
2	1	-.655	2.859	.821	-6.639	5.329
	3	-6.335	3.603	.095	-13.875	1.205
3	1	5.680	3.814	.153	-2.303	13.663
	2	6.335	3.603	.095	-1.205	13.875

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = Control probe

(3f) Experiment 1C: Accuracy data in learning condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	69.6750	14.59534	20
TBF	77.6650	13.54972	20
CONTROL	81.6600	12.76786	20

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.867	2.577	2	.276	.882	.966	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1489.602	2	744.801	5.236	.010
	Greenhouse-Geisser	1489.602	1.765	844.146	5.236	.013
	Huynh-Feldt	1489.602	1.932	771.160	5.236	.011
	Lower-bound	1489.602	1.000	1489.602	5.236	.034
Error(PROBE)	Sphericity Assumed	5405.844	38	142.259		
	Greenhouse-Geisser	5405.844	33.528	161.234		
	Huynh-Feldt	5405.844	36.701	147.294		
	Lower-bound	5405.844	19.000	284.518		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-7.990	4.232	.074	-16.847	.867
	3	-11.985*	3.945	.007	-20.241	-3.729
2	1	7.990	4.232	.074	-.867	16.847
	3	-3.995	3.035	.204	-10.347	2.357
3	1	11.985*	3.945	.007	3.729	20.241
	2	3.995	3.035	.204	-2.357	10.347

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

(4a) Experiment 1D: Response times data (between trained and untrained location sets)

Descriptive Statistics

	Mean	Std. Deviation	N
TR_TBR	1237,9667	469,98106	15
UNTR_TBR	1256,8000	312,05109	15
TR_TBF	1028,6333	231,58950	15
UNTR_TBF	999,9333	152,10345	15
TR_CON	949,1000	198,14472	15
UNTR_CON	999,8333	182,39661	15

TR_TBR = TBR probes with trained location set
UNTR_TBR = TBR probes with untrained location set
TR_TBF = TBF probes with trained location set
UNTR_TBF = TBF probes with untrained location set
TR_CON = Control probes with trained location set
UNTR_CON = Control probes with untrained location set

Estimates

Measure: MEASURE_1

BLOCK	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	1071,900	68,406	925,183	1218,617
2	1085,522	48,787	980,884	1190,160

Pairwise Comparisons

Measure: MEASURE_1

(I) BLOCK	(J) BLOCK	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-13,622	51,553	,795	-124,193	96,949
2	1	13,622	51,553	,795	-96,949	124,193

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of response times between trained and untrained location set, irrespective of probe type.

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	1247,383	94,920	1043,801	1450,966
2	1014,283	40,840	926,691	1101,875
3	974,467	39,608	889,516	1059,417

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	233,100*	75,211	,008	71,788	394,412
	3	272,917*	69,730	,002	123,381	422,473
2	1	-233,100*	75,211	,008	-394,412	-71,788
	3	39,817	20,785	,076	-4,763	84,396
3	1	-272,917*	69,730	,002	-422,473	-123,361
	2	-39,817	20,785	,076	-84,396	4,763

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of response times between probe types (conditions combined).1 = TBR probe, 2 = TBF probe, 3 = Control probe

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,207	20,482	2	,000	,558	,572	,500
BLOCK	1,000	,000	0	.	1,000	1,000	1,000
PROBE * BLOCK	,308	15,323	2	,000	,591	,613	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE+BLOCK+PROBE*BLOCK

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1304044,839	2	652022,419	11,908	,000
	Greenhouse-Geisser	1304044,839	1,115	1169139,950	11,908	,003
	Huynh-Feldt	1304044,839	1,143	1140609,222	11,908	,002
	Lower-bound	1304044,839	1,000	1304044,839	11,908	,004
Error(PROBE)	Sphericity Assumed	1533147,828	28	54755,280		
	Greenhouse-Geisser	1533147,828	15,615	98181,570		
	Huynh-Feldt	1533147,828	16,006	95785,628		
	Lower-bound	1533147,828	14,000	109510,559		
BLOCK	Sphericity Assumed	4175,211	1	4175,211	,070	,795
	Greenhouse-Geisser	4175,211	1,000	4175,211	,070	,795
	Huynh-Feldt	4175,211	1,000	4175,211	,070	,795
	Lower-bound	4175,211	1,000	4175,211	,070	,795
Error(BLOCK)	Sphericity Assumed	837187,789	14	59799,128		
	Greenhouse-Geisser	837187,789	14,000	59799,128		
	Huynh-Feldt	837187,789	14,000	59799,128		
	Lower-bound	837187,789	14,000	59799,128		
PROBE * BLOCK	Sphericity Assumed	23966,706	2	11983,353	,594	,559
	Greenhouse-Geisser	23966,706	1,182	20279,701	,594	,479
	Huynh-Feldt	23966,706	1,227	19533,770	,594	,484
	Lower-bound	23966,706	1,000	23966,706	,594	,454
Error(PROBE*BLOCK)	Sphericity Assumed	565107,794	28	20182,421		
	Greenhouse-Geisser	565107,794	16,545	34155,171		
	Huynh-Feldt	565107,794	17,177	32898,871		
	Lower-bound	565107,794	14,000	40364,842		

Block = trained versus untrained location set

(4b) Experiment 1D: Response times with untrained location set

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	1256,8000	312,05109	15
TBF	999,9333	152,10345	15
CONTROL	999,8333	182,39661	15

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,290	16,089	2	,000	,585	,606	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	660061,811	2	330030,906	14,143	,000
	Greenhouse-Geisser	660061,811	1,170	564326,460	14,143	,001
	Huynh-Feldt	660061,811	1,212	544805,498	14,143	,001
	Lower-bound	660061,811	1,000	660061,811	14,143	,002
Error(PROBE)	Sphericity Assumed	653406,522	28	23335,947		
	Greenhouse-Geisser	653406,522	16,375	39902,604		
	Huynh-Feldt	653406,522	16,962	38522,308		
	Lower-bound	653406,522	14,000	46671,894		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	256,867*	63,647	,001	120,357	393,376
	3	256,967*	69,002	,002	108,972	404,962
2	1	-256,867*	63,647	,001	-393,376	-120,357
	3	1,000E-01	22,850	,997	-48,908	49,108
3	1	-256,967*	69,002	,002	-404,962	-108,972
	2	-1,000E-01	22,850	,997	-49,108	48,908

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(4c) Experiment 1D: Response times with trained location set

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	1237,9667	469,98106	15
TBF	1028,6333	231,58950	15
CONTROL	949,1000	198,14472	15

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,198	21,069	2	,000	,555	,568	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	667949,733	2	333974,867	6,472	,005
	Greenhouse-Geisser	667949,733	1,110	601904,822	6,472	,020
	Huynh-Feldt	667949,733	1,136	587881,673	6,472	,019
	Lower-bound	667949,733	1,000	667949,733	6,472	,023
Error(PROBE)	Sphericity Assumed	1444849,100	28	51601,754		
	Greenhouse-Geisser	1444849,100	15,536	92999,047		
	Huynh-Feldt	1444849,100	15,907	90832,360		
	Lower-bound	1444849,100	14,000	103203,507		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	209,333	104,088	,064	-13,913	432,580
	3	288,867*	94,851	,009	85,432	492,301
2	1	-209,333	104,088	,064	-432,580	13,913
	3	79,533*	28,456	,014	18,501	140,566
3	1	-288,867*	94,851	,009	-492,301	-85,432
	2	-79,533*	28,456	,014	-140,566	-18,501

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(4d) Experiment 1D: Accuracy data (between trained and untrained location sets)

Descriptive Statistics

	Mean	Std. Deviation	N
TR_TBR	68,8533	14,57414	15
UNTR_TBR	56,0067	18,90017	15
TR_TBF	80,6600	10,78847	15
UNTR_TBF	82,2267	7,83905	15
TR_CON	80,6667	9,94432	15
UNTR_CON	90,9000	8,40009	15

TR_TBR = TBR probes with trained location set
UNTR_TBR = TBR probes with untrained location set
TR_TBF = TBF probes with trained location set
UNTR_TBF = TBF probes with untrained location set
TR_CON = Control probes with trained location set
UNTR_CON = Control probes with untrained location set

Estimates

Measure: MEASURE_1

BLOCK	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	76,727	1,410	73,703	79,751
2	76,378	1,716	72,697	80,059

Pairwise Comparisons

Measure: MEASURE_1

(I) BLOCK	(J) BLOCK	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	,349	1,707	,841	-3,312	4,010
2	1	-,349	1,707	,841	-4,010	3,312

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of accuracy between trained and untrained location set, irrespective of probe type.

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	62,430	4,181	53,464	71,396
2	81,443	1,803	77,576	85,311
3	85,783	2,058	81,370	90,196

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-19,013*	5,117	,002	-29,988	-8,038
	3	-23,353*	5,230	,001	-34,570	-12,137
2	1	19,013*	5,117	,002	8,038	29,988
	3	-4,340	2,389	,091	-9,463	,783
3	1	23,353*	5,230	,001	12,137	34,570
	2	4,340	2,389	,091	-,783	9,463

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of accuracy between probe types (conditions combined).1 = TBR probe, 2 = TBF probe, 3 = Control probe

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,493	9,188	2	,010	,664	,707	,500
BLOCK	1,000	,000	0	.	1,000	1,000	1,000
PROBE * BLOCK	,924	1,030	2	,597	,929	1,000	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE+BLOCK+PROBE*BLOCK

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	9257,206	2	4628,603	15,626	,000
	Greenhouse-Geisser	9257,206	1,327	6974,149	15,626	,000
	Huynh-Feldt	9257,206	1,413	6550,007	15,626	,000
	Lower-bound	9257,206	1,000	9257,206	15,626	,001
Error(PROBE)	Sphericity Assumed	8293,764	28	296,206		
	Greenhouse-Geisser	8293,764	18,583	446,308		
	Huynh-Feldt	8293,764	19,786	419,165		
	Lower-bound	8293,764	14,000	592,412		
BLOCK	Sphericity Assumed	2,739	1	2,739	,042	,841
	Greenhouse-Geisser	2,739	1,000	2,739	,042	,841
	Huynh-Feldt	2,739	1,000	2,739	,042	,841
	Lower-bound	2,739	1,000	2,739	,042	,841
Error(BLOCK)	Sphericity Assumed	917,906	14	65,565		
	Greenhouse-Geisser	917,906	14,000	65,565		
	Huynh-Feldt	917,906	14,000	65,565		
	Lower-bound	917,906	14,000	65,565		
PROBE * BLOCK	Sphericity Assumed	2038,854	2	1019,427	19,894	,000
	Greenhouse-Geisser	2038,854	1,858	1097,087	19,894	,000
	Huynh-Feldt	2038,854	2,000	1019,427	19,894	,000
	Lower-bound	2038,854	1,000	2038,854	19,894	,001
Error(PROBE*BLOCK)	Sphericity Assumed	1434,776	28	51,242		
	Greenhouse-Geisser	1434,776	26,018	55,146		
	Huynh-Feldt	1434,776	28,000	51,242		
	Lower-bound	1434,776	14,000	102,484		

Block = trained versus untrained location set.

(4e) Experiment 1D: Accuracy data with untrained location set

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	56,0067	18,90017	15
TBF	82,2267	7,83905	15
CONTROL	90,9000	8,40009	15

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,440	10,683	2	,005	,641	,677	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	9901,299	2	4950,650	27,761	,000
	Greenhouse-Geisser	9901,299	1,282	7724,797	27,761	,000
	Huynh-Feldt	9901,299	1,354	7310,156	27,761	,000
	Lower-bound	9901,299	1,000	9901,299	27,761	,000
Error(PROBE)	Sphericity Assumed	4993,314	28	178,333		
	Greenhouse-Geisser	4993,314	17,945	278,263		
	Huynh-Feldt	4993,314	18,962	263,327		
	Lower-bound	4993,314	14,000	356,665		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-26,220*	5,151	,000	-37,269	-15,171
	3	-34,893*	6,134	,000	-48,050	-21,737
2	1	26,220*	5,151	,000	15,171	37,269
	3	-8,673*	2,678	,006	-14,416	-2,930
3	1	34,893*	6,134	,000	21,737	48,050
	2	8,673*	2,678	,006	2,930	14,416

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(4f) Experiment 1D: Accuracy data with trained location set

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	68,8533	14,57414	15
TBF	80,6600	10,78847	15
CONT	80,6667	9,94432	15

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,606	6,506	2	,039	,717	,777	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1394,761	2	697,381	4,124	,027
	Greenhouse-Geisser	1394,761	1,435	971,971	4,124	,043
	Huynh-Feldt	1394,761	1,554	897,590	4,124	,039
	Lower-bound	1394,761	1,000	1394,761	4,124	,062
Error(PROBE)	Sphericity Assumed	4735,225	28	169,115		
	Greenhouse-Geisser	4735,225	20,090	235,704		
	Huynh-Feldt	4735,225	21,755	217,666		
	Lower-bound	4735,225	14,000	338,230		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-11,807	5,772	,060	-24,187	,573
	3	-11,813*	5,011	,033	-22,561	-1,065
2	1	11,807	5,772	,060	-,573	24,187
	3	-6,667E-03	3,036	,998	-6,518	6,504
3	1	11,813*	5,011	,033	1,065	22,561
	2	6,667E-03	3,036	,998	-6,504	6,518

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(5a) Experiment 1E: Response times data (across set sizes/probe types)

Descriptive Statistics

	Mean	Std. Deviation	N
R2F2TBR	945.6458	270.58662	24
R4F4TBR	1036.7083	299.38059	24
R2F4TBR	960.5417	257.84508	24
R4F2TBR	1070.8333	306.69510	24
R2F2TBF	788.9375	211.58210	24
R4F4TBF	924.1667	273.19632	24
R2F4TBF	800.7708	216.33428	24
R4F2TBF	958.4167	272.78721	24
R2F2CONT	789.1250	202.37929	24
R4F4CONT	920.3750	249.14791	24
R2F4CONT	838.1667	259.09167	24
R4F2CONT	961.3333	236.75646	24

R2F2 = TBR set size: 2; TBF set size: 2
R4F4 = TBR set size: 4; TBF set size: 4
R2F4 = TBR set size: 2; TBF set size: 4
R4F2 = TBR set size: 4; TBF set size: 2

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	1003.432	54.359	890.983	1115.881
2	868.073	45.215	774.539	961.607
3	877.250	44.385	785.433	969.067

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	135.359*	30.104	.000	73.084	197.634
	3	126.182*	31.163	.000	61.717	190.647
2	1	-135.359*	30.104	.000	-197.634	-73.084
	3	-9.177	21.181	.669	-52.994	34.640
3	1	-126.182*	31.163	.000	-190.647	-61.717
	2	9.177	21.181	.669	-34.640	52.994

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Response times between probe types irrespective of set size. 1 = TBR probe, 2 = TBF probe, 3 = Control probe.

Estimates

Measure: MEASURE_1

TBF_set_size	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	919.049	43.923	828.187	1009.910
2	913.455	47.757	814.662	1012.247

Response times with either 2 TBF items (1) or 4 TBF items (2), irrespective of probe type or TBR set size.

Estimates

Measure: MEASURE_1

TBR_set_size	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	853.865	43.244	764.408	943.322
2	978.639	48.568	878.172	1079.106

Response times with either 2 TBR items (1) or 4 TBR items (2), irrespective of probe type or TBF set size.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
probe_type	.820	4.362	2	.113	.848	.908	.500
TBR_set_size	1.000	.000	0	.	1.000	1.000	1.000
TBF_set_size	1.000	.000	0	.	1.000	1.000	1.000
probe_type * TBR_set_size	.879	2.828	2	.243	.892	.962	.500
probe_type * TBF_set_size	.962	.855	2	.652	.963	1.000	.500
TBR_set_size * TBF_set_size	1.000	.000	0	.	1.000	1.000	1.000
probe_type * TBR_set_size * TBF_set_size	.765	5.906	2	.052	.809	.862	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: probe_type+TBR_set_size+TBF_set_size+probe_type*TBR_set_size+probe_type*TBF_set_size+TBR_set_size*TBF_set_size+probe_type*TBR_set_size*TBF_set_size

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
probe_type	Sphericity Assumed	1098507.200	2	549253.600	14.758	.000
	Greenhouse-Geisser	1098507.200	1.695	648045.583	14.758	.000
	Huynh-Feldt	1098507.200	1.816	605015.779	14.758	.000
	Lower-bound	1098507.200	1.000	1098507.200	14.758	.001
Error(probe_type)	Sphericity Assumed	1711950.259	46	37216.310		
	Greenhouse-Geisser	1711950.259	38.987	43910.254		
	Huynh-Feldt	1711950.259	41.760	40994.642		
	Lower-bound	1711950.259	23.000	74432.620		
TBR_set_size	Sphericity Assumed	1120941.168	1	1120941.168	78.269	.000
	Greenhouse-Geisser	1120941.168	1.000	1120941.168	78.269	.000
	Huynh-Feldt	1120941.168	1.000	1120941.168	78.269	.000
	Lower-bound	1120941.168	1.000	1120941.168	78.269	.000
Error(TBR_set_size)	Sphericity Assumed	329398.312	23	14321.666		
	Greenhouse-Geisser	329398.312	23.000	14321.666		
	Huynh-Feldt	329398.312	23.000	14321.666		
	Lower-bound	329398.312	23.000	14321.666		
TBF_set_size	Sphericity Assumed	2252.883	1	2252.883	.194	.664
	Greenhouse-Geisser	2252.883	1.000	2252.883	.194	.664
	Huynh-Feldt	2252.883	1.000	2252.883	.194	.664
	Lower-bound	2252.883	1.000	2252.883	.194	.664
Error(TBF_set_size)	Sphericity Assumed	267187.096	23	11616.830		
	Greenhouse-Geisser	267187.096	23.000	11616.830		
	Huynh-Feldt	267187.096	23.000	11616.830		
	Lower-bound	267187.096	23.000	11616.830		
probe_type * TBR_set_size	Sphericity Assumed	25341.470	2	12670.735	.775	.466
	Greenhouse-Geisser	25341.470	1.785	14199.244	.775	.454
	Huynh-Feldt	25341.470	1.925	13166.498	.775	.462
	Lower-bound	25341.470	1.000	25341.470	.775	.388
Error(probe_type*TBR_set_size)	Sphericity Assumed	751679.988	46	16340.869		
	Greenhouse-Geisser	751679.988	41.048	18312.118		
	Huynh-Feldt	751679.988	44.268	16980.232		
	Lower-bound	751679.988	23.000	32681.739		
probe_type * TBF_set_size	Sphericity Assumed	3372.766	2	1686.383	.111	.895
	Greenhouse-Geisser	3372.766	1.927	1750.700	.111	.888
	Huynh-Feldt	3372.766	2.000	1686.383	.111	.895
	Lower-bound	3372.766	1.000	3372.766	.111	.742
Error(probe_type*TBF_set_size)	Sphericity Assumed	698682.693	46	15188.754		
	Greenhouse-Geisser	698682.693	44.310	15768.038		
	Huynh-Feldt	698682.693	46.000	15188.754		
	Lower-bound	698682.693	23.000	30377.508		
TBR_set_size * TBF_set_size	Sphericity Assumed	68527.105	1	68527.105	5.069	.034
	Greenhouse-Geisser	68527.105	1.000	68527.105	5.069	.034
	Huynh-Feldt	68527.105	1.000	68527.105	5.069	.034
	Lower-bound	68527.105	1.000	68527.105	5.069	.034
Error(TBR_set_size*TBF_set_size)	Sphericity Assumed	310911.541	23	13517.893		
	Greenhouse-Geisser	310911.541	23.000	13517.893		
	Huynh-Feldt	310911.541	23.000	13517.893		
	Lower-bound	310911.541	23.000	13517.893		
probe_type * TBR_set_size * TBF_set_size	Sphericity Assumed	7233.189	2	3616.595	.388	.681
	Greenhouse-Geisser	7233.189	1.619	4468.108	.388	.638
	Huynh-Feldt	7233.189	1.724	4196.581	.388	.650
	Lower-bound	7233.189	1.000	7233.189	.388	.540
Error(probe_type*TBR_set_size*TBF_set_size)	Sphericity Assumed	429187.602	46	9330.165		
	Greenhouse-Geisser	429187.602	37.234	11526.918		
	Huynh-Feldt	429187.602	39.643	10826.427		
	Lower-bound	429187.602	23.000	18660.331		

(5b) Experiment 1E: Response times data with 2 TBR items and 2 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	943,4792	268,83102	24
TBF	781,6042	217,58541	24
CONTROL	783,9583	203,20689	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,645	9,656	2	,008	,738	,776	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	413247,632	2	206623,816	19,576	,000
	Greenhouse-Geisser	413247,632	1,476	280029,291	19,576	,000
	Huynh-Feldt	413247,632	1,553	266173,357	19,576	,000
	Lower-bound	413247,632	1,000	413247,632	19,576	,000
Error(PROBE)	Sphericity Assumed	485515,868	46	10554,693		
	Greenhouse-Geisser	485515,868	33,942	14304,368		
	Huynh-Feldt	485515,868	35,709	13596,584		
	Lower-bound	485515,868	23,000	21109,386		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	161,875*	34,272	,000	90,979	232,771
	3	159,521*	33,277	,000	90,681	228,360
2	1	-161,875*	34,272	,000	-232,771	-90,979
	3	-2,354	18,888	,902	-41,426	36,718
3	1	-159,521*	33,277	,000	-228,360	-90,681
	2	2,354	18,888	,902	-36,718	41,426

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = TBF probe

(5c) Experiment 1E: Response times data with 4 TBR items and 4 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	1078,0625	345,46907	24
TBF	894,9167	256,30309	24
CONTROL	891,9375	230,78125	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,828	4,152	2	,125	,853	,915	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	545550,299	2	272775,149	11,590	,000
	Greenhouse-Geisser	545550,299	1,707	319687,233	11,590	,000
	Huynh-Feldt	545550,299	1,829	298197,403	11,590	,000
	Lower-bound	545550,299	1,000	545550,299	11,590	,002
Error(PROBE)	Sphericity Assumed	1082628,035	46	23535,392		
	Greenhouse-Geisser	1082628,035	39,250	27583,027		
	Huynh-Feldt	1082628,035	42,078	25728,857		
	Lower-bound	1082628,035	23,000	47070,784		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	183,146*	48,642	,001	82,522	283,769
	3	186,125*	48,681	,001	85,420	286,830
2	1	-183,146*	48,642	,001	-283,769	-82,522
	3	2,979	33,881	,931	-67,109	73,068
3	1	-186,125*	48,681	,001	-286,830	-85,420
	2	-2,979	33,881	,931	-73,068	67,109

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = TBF probe

(5d) Experiment 1E: Response times data with 2 TBR items and 4 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	987.4167	297.39425	24
TBF	779.4417	226.03862	24
CONTROL	826.4583	255.74375	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,740	6,618	2	,037	,794	,843	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	570974,021	2	285487,011	16,246	,000
	Greenhouse-Geisser	570974,021	1,588	359654,073	16,246	,000
	Huynh-Feldt	570974,021	1,686	338654,310	16,246	,000
	Lower-bound	570974,021	1,000	570974,021	16,246	,001
Error(PROBE)	Sphericity Assumed	808344,486	46	17572,706		
	Greenhouse-Geisser	808344,486	36,514	22137,944		
	Huynh-Feldt	808344,486	38,778	20845,336		
	Lower-bound	808344,486	23,000	35145,412		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	207,975*	44,678	,000	115,551	300,399
	3	160,958*	40,647	,001	76,874	245,042
2	1	-207,975*	44,678	,000	-300,399	-115,551
	3	-47,017	27,293	,098	-103,476	9,443
3	1	-160,958*	40,647	,001	-245,042	-76,874
	2	47,017	27,293	,098	-9,443	103,476

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe
2 = TBF probe
3 = TBF probe

(5e) Experiment 1E: Response times data with 4 TBR items and 2 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	1090,3958	298,12293	24
TBF	943,1458	271,33216	24
CONTROL	959,2917	274,56281	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,950	1,131	2	,568	,952	1,000	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	313052,424	2	156526,212	4,080	,023
	Greenhouse-Geisser	313052,424	1,905	164370,616	4,080	,025
	Huynh-Feldt	313052,424	2,000	156526,212	4,080	,023
	Lower-bound	313052,424	1,000	313052,424	4,080	,055
Error(PROBE)	Sphericity Assumed	1764926,576	46	38367,969		
	Greenhouse-Geisser	1764926,576	43,805	40290,803		
	Huynh-Feldt	1764926,576	46,000	38367,969		
	Lower-bound	1764926,576	23,000	76735,938		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	147,250*	59,648	,021	23,859	270,641
	3	131,104*	59,603	,038	7,806	254,403
2	1	-147,250*	59,648	,021	-270,641	-23,859
	3	-16,146	49,815	,749	-119,197	86,905
3	1	-131,104*	59,603	,038	-254,403	-7,806
	2	16,146	49,815	,749	-86,905	119,197

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probe, 2 = TBF probe, 3 = TBF probe

(5f) Experiment 1E: Accuracy data (across set sizes)

Descriptive Statistics

	Mean	Std. Deviation	N
R2F2TBR	79.1667	10.27782	24
R4F4TBR	67.2250	14.95385	24
R2F4TBR	74.7250	16.78592	24
R4F2TBR	69.1667	16.42876	24
R2F2TBF	91.6625	8.62563	24
R4F4TBF	84.1583	10.91230	24
R2F4TBF	88.3458	11.81808	24
R4F2TBF	84.4500	9.55301	24
R2F2CONT	91.1083	9.14373	24
R4F4CONT	78.3292	15.87773	24
R2F4CONT	89.1667	9.17414	24
R4F2CONT	79.7250	15.28345	24

R2F2 = TBR set size: 2; TBF set size: 2
R4F4 = TBR set size: 4; TBF set size: 4
R2F4 = TBR set size: 2; TBF set size: 4
R4F2 = TBR set size: 4; TBF set size: 2

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	72.571	2.123	68.178	76.963
2	87.154	1.656	83.729	90.579
3	84.582	2.247	79.934	89.231

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-14.583*	1.717	.000	-18.135	-11.032
	3	-12.011*	2.302	.000	-16.775	-7.248
2	1	14.583*	1.717	.000	11.032	18.135
	3	2.572	1.506	.101	-.543	5.687
3	1	12.011*	2.302	.000	7.248	16.775
	2	-2.572	1.506	.101	-5.687	.543

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Accuracy between probe types (irrespective of set size). 1 = TBR probes, 2 = TBF probes, 3 = Control probes.

Estimates

Measure: MEASURE_1

TBR_set_size	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	85.696	1.514	82.565	88.827
2	77.176	2.105	72.822	81.530

Accuracy with 2 TBR items (1) or 4 TBR items (2), irrespective of probe type or TBF set size.

Estimates

Measure: MEASURE_1

TBF_set_size	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	82.547	1.877	78.663	86.430
2	80.325	1.712	76.783	83.867

Accuracy with 2 TBF items (1) or 4 TBF items (2), irrespective of probe type or TBR set size.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
probe_type	.725	7.074	2	.029	.784	.832	.500
TBR_set_size	1.000	.000	0	.	1.000	1.000	1.000
TBF_set_size	1.000	.000	0	.	1.000	1.000	1.000
probe_type * TBR_set_size	.943	1.289	2	.525	.946	1.000	.500
probe_type * TBF_set_size	.843	3.756	2	.153	.864	.928	.500
TBR_set_size * TBF_set_size	1.000	.000	0	.	1.000	1.000	1.000
probe_type * TBR_set_size * TBF_set_size	.763	5.958	2	.051	.808	.860	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: probe_type+TBR_set_size+TBF_set_size+probe_type*TBR_set_size+probe_type*TBF_set_size+TBR_set_size*TBF_set_size+probe_type*TBR_set_size*TBF_set_size

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
probe_type	Sphericity Assumed	11634.025	2	5817.013	34.570	.000
	Greenhouse-Geisser	11634.025	1.569	7416.500	34.570	.000
	Huynh-Feldt	11634.025	1.663	6994.290	34.570	.000
	Lower-bound	11634.025	1.000	11634.025	34.570	.000
Error(probe_type)	Sphericity Assumed	7740.363	46	168.269		
	Greenhouse-Geisser	7740.363	36.079	214.537		
	Huynh-Feldt	7740.363	38.257	202.324		
	Lower-bound	7740.363	23.000	336.538		
TBR_set_size	Sphericity Assumed	5226.679	1	5226.679	42.258	.000
	Greenhouse-Geisser	5226.679	1.000	5226.679	42.258	.000
	Huynh-Feldt	5226.679	1.000	5226.679	42.258	.000
	Lower-bound	5226.679	1.000	5226.679	42.258	.000
Error(TBR_set_size)	Sphericity Assumed	2844.737	23	123.684		
	Greenhouse-Geisser	2844.737	23.000	123.684		
	Huynh-Feldt	2844.737	23.000	123.684		
	Lower-bound	2844.737	23.000	123.684		
TBF_set_size	Sphericity Assumed	355.333	1	355.333	4.160	.053
	Greenhouse-Geisser	355.333	1.000	355.333	4.160	.053
	Huynh-Feldt	355.333	1.000	355.333	4.160	.053
	Lower-bound	355.333	1.000	355.333	4.160	.053
Error(TBF_set_size)	Sphericity Assumed	1964.459	23	85.411		
	Greenhouse-Geisser	1964.459	23.000	85.411		
	Huynh-Feldt	1964.459	23.000	85.411		
	Lower-bound	1964.459	23.000	85.411		
probe_type * TBR_set_size	Sphericity Assumed	353.173	2	176.587	2.149	.128
	Greenhouse-Geisser	353.173	1.892	186.638	2.149	.131
	Huynh-Feldt	353.173	2.000	176.587	2.149	.128
	Lower-bound	353.173	1.000	353.173	2.149	.156
Error(probe_type*TBR_set_size)	Sphericity Assumed	3780.318	46	82.181		
	Greenhouse-Geisser	3780.318	43.523	86.859		
	Huynh-Feldt	3780.318	46.000	82.181		
	Lower-bound	3780.318	23.000	164.362		
probe_type * TBF_set_size	Sphericity Assumed	34.102	2	17.051	.178	.838
	Greenhouse-Geisser	34.102	1.729	19.727	.178	.807
	Huynh-Feldt	34.102	1.856	18.370	.178	.822
	Lower-bound	34.102	1.000	34.102	.178	.677
Error(probe_type*TBF_set_size)	Sphericity Assumed	4409.283	46	95.854		
	Greenhouse-Geisser	4409.283	39.760	110.898		
	Huynh-Feldt	4409.283	42.697	103.268		
	Lower-bound	4409.283	23.000	191.708		
TBR_set_size * TBF_set_size	Sphericity Assumed	73.710	1	73.710	1.360	.255
	Greenhouse-Geisser	73.710	1.000	73.710	1.360	.255
	Huynh-Feldt	73.710	1.000	73.710	1.360	.255
	Lower-bound	73.710	1.000	73.710	1.360	.255
Error(TBR_set_size*TBF_set_size)	Sphericity Assumed	1246.456	23	54.194		
	Greenhouse-Geisser	1246.456	23.000	54.194		
	Huynh-Feldt	1246.456	23.000	54.194		
	Lower-bound	1246.456	23.000	54.194		
probe_type * TBR_set_size * TBF_set_size	Sphericity Assumed	20.481	2	10.241	.129	.879
	Greenhouse-Geisser	20.481	1.617	12.670	.129	.836
	Huynh-Feldt	20.481	1.721	11.902	.129	.850
	Lower-bound	20.481	1.000	20.481	.129	.723
Error(probe_type*TBR_set_size*TBF_set_size)	Sphericity Assumed	3650.300	46	79.354		
	Greenhouse-Geisser	3650.300	37.180	98.180		
	Huynh-Feldt	3650.300	39.578	92.231		
	Lower-bound	3650.300	23.000	158.709		

(5g) Experiment 1E: Accuracy data with 2 TBR items and 2 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	79.1667	10.27782	24
TBF	91.6625	8.62563	24
CONTROL	91.1083	9.14373	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.993	.149	2	.928	.993	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	2392.451	2	1196.225	41.064	.000
	Greenhouse-Geisser	2392.451	1.987	1204.305	41.064	.000
	Huynh-Feldt	2392.451	2.000	1196.225	41.064	.000
	Lower-bound	2392.451	1.000	2392.451	41.064	.000
Error(PROBE)	Sphericity Assumed	1340.029	46	29.131		
	Greenhouse-Geisser	1340.029	45.691	29.328		
	Huynh-Feldt	1340.029	46.000	29.131		
	Lower-bound	1340.029	23.000	58.262		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	-12.496*	1.570	.000	-15.743	-9.249
	3	-11.942*	1.606	.000	-15.264	-8.619
2	1	12.496*	1.570	.000	9.249	15.743
	3	.554	1.497	.715	-2.542	3.650
3	1	11.942*	1.606	.000	8.619	15.264
	2	-.554	1.497	.715	-3.650	2.542

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(5h) Experiment 1E: Accuracy data with 4 TBR items and 4 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	67.2250	14.95385	24
TBF	84.1583	10.91230	24
CONTROL	78.3292	15.87773	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.953	1.048	2	.592	.956	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	3552.156	2	1776.078	13.656	.000
	Greenhouse-Geisser	3552.156	1.911	1858.734	13.656	.000
	Huynh-Feldt	3552.156	2.000	1776.078	13.656	.000
	Lower-bound	3552.156	1.000	3552.156	13.656	.001
Error(PROBE)	Sphericity Assumed	5982.698	46	130.059		
	Greenhouse-Geisser	5982.698	43.954	136.111		
	Huynh-Feldt	5982.698	46.000	130.059		
	Lower-bound	5982.698	23.000	260.117		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	-16.933*	3.158	.000	-23.466	-10.401
	3	-11.104*	3.627	.006	-18.606	-3.602
2	1	16.933*	3.158	.000	10.401	23.466
	3	5.829	3.064	.070	-.510	12.168
3	1	11.104*	3.627	.006	3.602	18.606
	2	-5.829	3.064	.070	-12.168	.510

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(5i) Experiment 1E: Accuracy data with 2 TBR items and 4 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	74.7250	16.78592	24
TBF	88.3458	11.81808	24
CONTROL	89.1667	9.17414	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.702	7.796	2	.020	.770	.815	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	3158.101	2	1579.050	10.098	.000
	Greenhouse-Geisser	3158.101	1.540	2050.231	10.098	.001
	Huynh-Feldt	3158.101	1.630	1938.066	10.098	.001
	Lower-bound	3158.101	1.000	3158.101	10.098	.004
Error(PROBE)	Sphericity Assumed	7193.466	46	156.380		
	Greenhouse-Geisser	7193.466	35.428	203.043		
	Huynh-Feldt	7193.466	37.479	191.934		
	Lower-bound	7193.466	23.000	312.759		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	-13.621*	3.975	.002	-21.844	-5.397
	3	-14.442*	4.162	.002	-23.052	-5.831
2	1	13.621*	3.975	.002	5.397	21.844
	3	-.821	2.443	.740	-5.874	4.233
3	1	14.442*	4.162	.002	5.831	23.052
	2	.821	2.443	.740	-4.233	5.874

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(5j) Experiment 1E: Accuracy data with 4 TBR items and 2 TBF items

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	69.1667	16.42876	24
TBF	84.4500	9.55301	24
CONTROL	79.7250	15.28345	24

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.769	5.767	2	.056	.813	.866	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	2939.074	2	1469.537	13.349	.000
	Greenhouse-Geisser	2939.074	1.625	1808.402	13.349	.000
	Huynh-Feldt	2939.074	1.731	1697.637	13.349	.000
	Lower-bound	2939.074	1.000	2939.074	13.349	.001
Error(PROBE)	Sphericity Assumed	5064.072	46	110.089		
	Greenhouse-Geisser	5064.072	37.380	135.474		
	Huynh-Feldt	5064.072	39.819	127.176		
	Lower-bound	5064.072	23.000	220.177		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	-15.283*	3.018	.000	-21.526	-9.041
	3	-10.558*	3.609	.008	-18.024	-3.093
2	1	15.283*	3.018	.000	9.041	21.526
	3	4.725	2.322	.054	-.079	9.529
3	1	10.558*	3.609	.008	3.093	18.024
	2	-4.725	2.322	.054	-9.529	.079

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(6a) Experiment 2A: Response times data

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	894.5333	247.84272	30
TBF	832.7667	188.27931	30
CONTROL	828.3167	190.14588	30

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.772	7.259	2	.027	.814	.856	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	82195.706	2	41097.853	4.794	.012
	Greenhouse-Geisser	82195.706	1.628	50483.158	4.794	.018
	Huynh-Feldt	82195.706	1.711	48027.019	4.794	.016
	Lower-bound	82195.706	1.000	82195.706	4.794	.037
Error(PROBE)	Sphericity Assumed	497220.628	58	8572.769		
	Greenhouse-Geisser	497220.628	47.217	10530.489		
	Huynh-Feldt	497220.628	49.632	10018.153		
	Lower-bound	497220.628	29.000	17145.539		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	61.767*	25.749	.023	9.105	114.429
	3	66.217*	27.361	.022	10.256	122.177
2	1	-61.767*	25.749	.023	-114.429	-9.105
	3	4.450	17.405	.800	-31.146	40.046
3	1	-66.217*	27.361	.022	-122.177	-10.256
	2	-4.450	17.405	.800	-40.046	31.146

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(6b) Experiment 2A: Accuracy data

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	89.8333	9.78064	30
TBF	88.5000	8.00323	30
NEW	93.8333	6.78275	30

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.864	4.093	2	.129	.880	.933	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	462.222	2	231.111	3.539	.035
	Greenhouse-Geisser	462.222	1.761	262.542	3.539	.042
	Huynh-Feldt	462.222	1.866	247.765	3.539	.039
	Lower-bound	462.222	1.000	462.222	3.539	.070
Error(PROBE)	Sphericity Assumed	3787.778	58	65.307		
	Greenhouse-Geisser	3787.778	51.056	74.188		
	Huynh-Feldt	3787.778	54.101	70.013		
	Lower-bound	3787.778	29.000	130.613		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	1.333	2.348	.575	-3.469	6.136
	3	-4.000	2.176	.076	-8.451	.451
2	1	-1.333	2.348	.575	-6.136	3.469
	3	-5.333*	1.677	.003	-8.763	-1.904
3	1	4.000	2.176	.076	-.451	8.451
	2	5.333*	1.677	.003	1.904	8.763

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(7a) Experiment 2B: Response times data

Descriptive Statistics

	Mean	Std. Deviation	N
R	879.5109	180.97027	46
F	917.9565	209.96073	46
D	865.5652	213.97034	46

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.967	1.480	2	.477	.968	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	67733.438	2	33866.719	4.329	.016
	Greenhouse-Geisser	67733.438	1.936	34986.750	4.329	.017
	Huynh-Feldt	67733.438	2.000	33866.719	4.329	.016
	Lower-bound	67733.438	1.000	67733.438	4.329	.043
Error(PROBE)	Sphericity Assumed	704031.062	90	7822.567		
	Greenhouse-Geisser	704031.062	87.119	8081.273		
	Huynh-Feldt	704031.062	90.000	7822.567		
	Lower-bound	704031.062	45.000	15645.135		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-38.446*	16.730	.026	-72.142	-4.749
	3	13.946	19.557	.479	-25.445	53.336
2	1	38.446*	16.730	.026	4.749	72.142
	3	52.391*	18.919	.008	14.286	90.497
3	1	-13.946	19.557	.479	-53.336	25.445
	2	-52.391*	18.919	.008	-90.497	-14.286

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(7b) Experiment 2B: Accuracy data

Descriptive Statistics

	Mean	Std. Deviation	N
R	90.9783	7.42515	46
F	90.5435	7.61783	46
N	88.9130	10.48348	46

R = TBR probes, F = TBF probes, N = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.823	8.577	2	.014	.850	.879	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	109.058	2	54.529	.939	.395
	Greenhouse-Geisser	109.058	1.699	64.187	.939	.382
	Huynh-Feldt	109.058	1.759	62.008	.939	.385
	Lower-bound	109.058	1.000	109.058	.939	.338
Error(PROBE)	Sphericity Assumed	5224.275	90	58.048		
	Greenhouse-Geisser	5224.275	76.458	68.329		
	Huynh-Feldt	5224.275	79.145	66.009		
	Lower-bound	5224.275	45.000	116.095		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	.435	1.222	.724	-2.027	2.896
	3	2.065	1.678	.225	-1.315	5.445
2	1	-.435	1.222	.724	-2.896	2.027
	3	1.630	1.806	.371	-2.007	5.268
3	1	-2.065	1.678	.225	-5.445	1.315
	2	-1.630	1.806	.371	-5.268	2.007

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8a) Experiment 2C: Response times (across all delay conditions)

Descriptive Statistics

	Mean	Std. Deviation	N
R650	812.9706	189.93551	34
F650	799.8794	216.56834	34
D650	760.8676	189.57893	34
R1300	759.1765	220.04682	34
F1300	744.0147	227.26521	34
D1300	720.0441	191.39707	34
R2600	844.6912	244.59611	34
F2600	831.6471	252.38918	34
D2600	779.2206	196.62667	34
R5200	876.6765	234.24052	34
F5200	866.7941	267.39683	34
D5200	853.6912	283.53697	34

R650 = TBR probes at 650 ms interval, F650 = TBF probes at 650 interval, D650 = Control probes at 650 ms interval, R1300 = TBR probes at 1300 ms interval etc.

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
DELAY	Mean	Std. Error	Lower Bound	Upper Bound
1	791.239	32.220	725.687	856.792
2	741.078	34.838	670.199	811.958
3	818.520	37.858	741.497	895.542
4	865.721	42.262	779.738	951.703

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) DELAY	(J) DELAY	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	50.161*	21.494	.026	6.431	93.891
	3	-27.280	25.239	.288	-78.630	24.069
	4	-74.481*	27.624	.011	-130.684	-18.279
2	1	-50.161*	21.494	.026	-93.891	-6.431
	3	-77.441*	19.631	.000	-117.381	-37.501
	4	-124.642*	23.247	.000	-171.938	-77.346
3	1	27.280	25.239	.288	-24.069	78.630
	2	77.441*	19.631	.000	37.501	117.381
	4	-47.201	24.207	.060	-96.450	2.048
4	1	74.481*	27.624	.011	18.279	130.684
	2	124.642*	23.247	.000	77.346	171.938
	3	47.201	24.207	.060	-2.048	96.450

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of delay conditions, irrespective of probe type. 1 = 650 ms, 2 = 1300 ms, 3 = 2600 ms, 4 = 5200 ms.

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
PROBE	Mean	Std. Error	Lower Bound	Upper Bound
1	823.379	35.017	752.135	894.622
2	810.584	37.147	735.007	886.160
3	778.456	32.134	713.078	843.834

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	12.795	14.143	.372	-15.980	41.570
	3	44.923*	14.693	.004	15.030	74.816
2	1	-12.795	14.143	.372	-41.570	15.980
	3	32.128*	9.385	.002	13.034	51.221
3	1	-44.923*	14.693	.004	-74.816	-15.030
	2	-32.128*	9.385	.002	-51.221	-13.034

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of probe types, irrespective of delay conditions. 1 = TBR probes, 2 = TBF probes, 3 = Control probes.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
DELAY	.851	5.116	5	.402	.911	1.000	.333
PROBE	.771	8.335	2	.015	.813	.850	.500
DELAY * PROBE	.315	35.546	20	.018	.720	.842	.167

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: DELAY+PROBE+DELAY*PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
DELAY	Sphericity Assumed	830497.631	3	276832.544	9.653	.000
	Greenhouse-Geisser	830497.631	2.732	303951.453	9.653	.000
	Huynh-Feldt	830497.631	3.000	276832.544	9.653	.000
	Lower-bound	830497.631	1.000	830497.631	9.653	.004
Error(DELAY)	Sphericity Assumed	2839127.771	99	28678.058		
	Greenhouse-Geisser	2839127.771	90.167	31487.402		
	Huynh-Feldt	2839127.771	99.000	28678.058		
	Lower-bound	2839127.771	33.000	86034.175		
PROBE	Sphericity Assumed	145699.987	2	72849.993	6.377	.003
	Greenhouse-Geisser	145699.987	1.627	89554.355	6.377	.006
	Huynh-Feldt	145699.987	1.699	85734.927	6.377	.005
	Lower-bound	145699.987	1.000	145699.987	6.377	.017
Error(PROBE)	Sphericity Assumed	753974.857	66	11423.861		
	Greenhouse-Geisser	753974.857	53.689	14043.331		
	Huynh-Feldt	753974.857	56.081	13444.393		
	Lower-bound	753974.857	33.000	22847.723		
DELAY * PROBE	Sphericity Assumed	21427.873	6	3571.312	.491	.815
	Greenhouse-Geisser	21427.873	4.318	4962.160	.491	.757
	Huynh-Feldt	21427.873	5.049	4243.792	.491	.785
	Lower-bound	21427.873	1.000	21427.873	.491	.489
Error(DELAY*PROBE)	Sphericity Assumed	1441051.657	198	7278.039		
	Greenhouse-Geisser	1441051.657	142.502	10112.471		
	Huynh-Feldt	1441051.657	166.625	8648.496		
	Lower-bound	1441051.657	33.000	43668.232		

(8b) Experiment 2C: Response times (650 ms delay condition)

Descriptive Statistics

	Mean	Std. Deviation	N
R650	812.9706	189.93551	34
F650	799.8794	216.56834	34
D650	760.8676	189.57893	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.895	3.533	2	.171	.905	.955	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	49957.483	2	24978.741	3.835	.027
	Greenhouse-Geisser	49957.483	1.811	27589.857	3.835	.031
	Huynh-Feldt	49957.483	1.910	26158.857	3.835	.029
	Lower-bound	49957.483	1.000	49957.483	3.835	.059
Error(PROBE)	Sphericity Assumed	429882.891	66	6513.377		
	Greenhouse-Geisser	429882.891	59.754	7194.243		
	Huynh-Feldt	429882.891	63.023	6821.100		
	Lower-bound	429882.891	33.000	13026.754		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	13.091	22.100	.558	-31.872	58.055
	3	52.103*	19.673	.012	12.078	92.128
2	1	-13.091	22.100	.558	-58.055	31.872
	3	39.012*	16.552	.025	5.336	72.687
3	1	-52.103*	19.673	.012	-92.128	-12.078
	2	-39.012*	16.552	.025	-72.687	-5.336

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8c) Experiment 2C: Response times (1300 ms delay condition)

Descriptive Statistics

	Mean	Std. Deviation	N
R1300	759.1765	220.04682	34
F1300	744.0147	227.26521	34
D1300	720.0441	191.39707	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.958	1.368	2	.505	.960	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	26472.505	2	13236.252	2.051	.137
	Greenhouse-Geisser	26472.505	1.920	13790.077	2.051	.139
	Huynh-Feldt	26472.505	2.000	13236.252	2.051	.137
	Lower-bound	26472.505	1.000	26472.505	2.051	.161
Error(PROBE)	Sphericity Assumed	425837.995	66	6452.091		
	Greenhouse-Geisser	425837.995	63.349	6722.056		
	Huynh-Feldt	425837.995	66.000	6452.091		
	Lower-bound	425837.995	33.000	12904.182		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	15.162	19.399	.440	-24.306	54.629
	3	39.132	21.174	.074	-3.945	82.210
2	1	-15.162	19.399	.440	-54.629	24.306
	3	23.971	17.719	.185	-12.079	60.020
3	1	-39.132	21.174	.074	-82.210	3.945
	2	-23.971	17.719	.185	-60.020	12.079

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8d) Experiment 2C: Response times (2600 ms delay condition)

Descriptive Statistics

	Mean	Std. Deviation	N
R2600	844.6912	244.59611	34
F2600	831.6471	252.38918	34
D2600	779.2206	196.62667	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.835	5.781	2	.056	.858	.901	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	81657.593	2	40828.797	5.103	.009
	Greenhouse-Geisser	81657.593	1.716	47576.516	5.103	.012
	Huynh-Feldt	81657.593	1.801	45329.057	5.103	.011
	Lower-bound	81657.593	1.000	81657.593	5.103	.031
Error(PROBE)	Sphericity Assumed	528042.074	66	8000.637		
	Greenhouse-Geisser	528042.074	56.639	9322.892		
	Huynh-Feldt	528042.074	59.448	8882.489		
	Lower-bound	528042.074	33.000	16001.275		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	13.044	23.732	.586	-35.239	61.327
	3	65.471*	23.861	.010	16.925	114.016
2	1	-13.044	23.732	.586	-61.327	35.239
	3	52.426*	16.713	.004	18.423	86.430
3	1	-65.471*	23.861	.010	-114.016	-16.925
	2	-52.426*	16.713	.004	-86.430	-18.423

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8e) Experiment 2C: Response times (5200 ms delay condition)

Descriptivo Statistics

	Mean	Std. Deviation	N
R5200	876.6765	234.24052	34
F5200	866.7941	267.39683	34
D5200	853.6912	283.53697	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.764	8.627	2	.013	.809	.844	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	9040.279	2	4520.140	.368	.694
	Greenhouse-Geisser	9040.279	1.618	5588.309	.368	.649
	Huynh-Feldt	9040.279	1.689	5352.692	.368	.658
	Lower-bound	9040.279	1.000	9040.279	.368	.548
Error(PROBE)	Sphericity Assumed	811263.554	66	12291.872		
	Greenhouse-Geisser	811263.554	53.385	15196.607		
	Huynh-Feldt	811263.554	55.734	14555.879		
	Lower-bound	811263.554	33.000	24583.744		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	9.882	23.221	.673	-37.361	57.126
	3	22.985	32.778	.488	-43.703	89.673
2	1	-9.882	23.221	.673	-57.126	37.361
	3	13.103	23.569	.582	-34.850	61.055
3	1	-22.985	32.778	.488	-89.673	43.703
	2	-13.103	23.569	.582	-61.055	34.850

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8f) Experiment 2C: Accuracy data (across all delay conditions)

Descriptive Statistics

	Mean	Std. Deviation	N
R650	88.0382	10.72782	34
F650	90.7794	9.98522	34
D650	95.8765	6.77115	34
R1300	91.5676	10.01988	34
F1300	92.9324	7.14048	34
D1300	94.1088	9.10472	34
R2600	89.0176	11.47166	34
F2600	93.3324	7.51030	34
D2600	90.5824	12.29004	34
R5200	83.9176	11.14637	34
F5200	87.7471	9.79766	34
D5200	91.5676	11.16786	34

R650 = TBR probes at 650 ms interval, F650 = TBF probes at 650 interval, D650 = Control probes at 650 ms interval, R1300 = TBR probes at 1300 ms interval etc.

Estimates

Measure: MEASURE_1

DELAY	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	91.565	1.148	89.229	93.901
2	92.870	.956	90.925	94.815
3	90.977	1.381	88.168	93.787
4	87.744	1.146	85.413	90.075

Pairwise Comparisons

Measure: MEASURE_1

(I) DELAY	(J) DELAY	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1	2	-1.305	1.131	.257	-3.605	.995
	3	.587	1.161	.616	-1.776	2.950
	4	3.821*	1.178	.003	1.425	6.216
2	1	1.305	1.131	.257	-.995	3.605
	3	1.892	1.198	.124	-.546	4.330
	4	5.125*	1.064	.000	2.961	7.290
3	1	-.587	1.161	.616	-2.950	1.776
	2	-1.892	1.198	.124	-4.330	.546
	4	3.233*	1.233	.013	.724	5.742
4	1	-3.821*	1.178	.003	-6.216	-1.425
	2	-5.125*	1.064	.000	-7.290	-2.961
	3	-3.233*	1.233	.013	-5.742	-.724

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of delay conditions, irrespective of probe type. 1 = 650 ms, 2 = 1300 ms, 3 = 2600 ms, 4 = 5200 ms.

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	88.135	1.193	85.708	90.562
2	91.198	1.123	88.913	93.482
3	93.034	1.405	90.176	95.891

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-3.063*	1.374	.033	-5.859	-.266
	3	-4.899*	1.541	.003	-8.034	-1.763
2	1	3.063*	1.374	.033	.266	5.859
	3	-1.836	1.413	.203	-4.711	1.039
3	1	4.899*	1.541	.003	1.763	8.034
	2	1.836	1.413	.203	-1.039	4.711

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of probe types, irrespective of delay conditions. 1 = TBR probes, 2 = TBF probes, 3 = Control probes.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
DELAY	.966	1.092	5	.955	.977	1.000	.333
PROBE	.980	.646	2	.724	.980	1.000	.500
DELAY * PROBE	.228	45.438	20	.001	.710	.829	.167

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: DELAY+PROBE+DELAY*PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
DELAY	Sphericity Assumed	1452.222	3	484.074	7.028	.000
	Greenhouse-Geisser	1452.222	2.932	495.287	7.028	.000
	Huynh-Feldt	1452.222	3.000	484.074	7.028	.000
	Lower-bound	1452.222	1.000	1452.222	7.028	.012
Error(DELAY)	Sphericity Assumed	6818.762	99	68.876		
	Greenhouse-Geisser	6818.762	96.759	70.472		
	Huynh-Feldt	6818.762	99.000	68.876		
	Lower-bound	6818.762	33.000	206.629		
PROBE	Sphericity Assumed	1665.796	2	832.898	5.868	.005
	Greenhouse-Geisser	1665.796	1.961	849.548	5.868	.005
	Huynh-Feldt	1665.796	2.000	832.898	5.868	.005
	Lower-bound	1665.796	1.000	1665.796	5.868	.021
Error(PROBE)	Sphericity Assumed	9367.614	66	141.934		
	Greenhouse-Geisser	9367.614	64.706	144.771		
	Huynh-Feldt	9367.614	66.000	141.934		
	Lower-bound	9367.614	33.000	283.867		
DELAY * PROBE	Sphericity Assumed	839.407	6	139.901	2.476	.025
	Greenhouse-Geisser	839.407	4.261	196.979	2.476	.043
	Huynh-Feldt	839.407	4.972	168.828	2.476	.034
	Lower-bound	839.407	1.000	839.407	2.476	.125
Error(DELAY*PROBE)	Sphericity Assumed	11186.696	198	56.498		
	Greenhouse-Geisser	11186.696	140.626	79.549		
	Huynh-Feldt	11186.696	164.075	68.180		
	Lower-bound	11186.696	33.000	338.991		

(8g) Experiment 2C: Accuracy data (650 ms delay condition)

Descriptive Statistics

	Mean	Std. Deviation	N
R650	88.0382	10.72782	34
F650	90.7794	9.98522	34
D650	95.8765	6.77115	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.929	2.347	2	.309	.934	.988	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1075.896	2	537.948	8.527	.001
	Greenhouse-Geisser	1075.896	1.868	575.995	8.527	.001
	Huynh-Feldt	1075.896	1.976	544.559	8.527	.001
	Lower-bound	1075.896	1.000	1075.896	8.527	.006
Error(PROBE)	Sphericity Assumed	4163.697	66	63.086		
	Greenhouse-Geisser	4163.697	61.640	67.548		
	Huynh-Feldt	4163.697	65.199	63.862		
	Lower-bound	4163.697	33.000	126.173		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-2.741	1.890	.156	-6.587	1.105
	3	-7.838*	2.151	.001	-12.214	-3.462
2	1	2.741	1.890	.156	-1.105	6.587
	3	-5.097*	1.713	.005	-8.581	-1.613
3	1	7.838*	2.151	.001	3.462	12.214
	2	5.097*	1.713	.005	1.613	8.581

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8h) Experiment 2C: Accuracy data (1300 ms delay condition)

Descriptive Statistics

	Mean	Std. Deviation	N
R1300	91.5676	10.01988	34
F1300	92.9324	7.14048	34
D1300	94.1088	9.10472	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.871	4.420	2	.110	.886	.932	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	109.980	2	54.990	.780	.463
	Greenhouse-Geisser	109.980	1.771	62.084	.780	.449
	Huynh-Feldt	109.980	1.865	58.982	.780	.455
	Lower-bound	109.980	1.000	109.980	.780	.384
Error(PROBE)	Sphericity Assumed	4655.247	66	70.534		
	Greenhouse-Geisser	4655.247	58.458	79.634		
	Huynh-Feldt	4655.247	61.533	75.655		
	Lower-bound	4655.247	33.000	141.068		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-1.365	2.063	.513	-5.561	2.832
	3	-2.541	2.320	.281	-7.262	2.179
2	1	1.365	2.063	.513	-2.832	5.561
	3	-1.176	1.676	.488	-4.586	2.233
3	1	2.541	2.320	.281	-2.179	7.262
	2	1.176	1.676	.488	-2.233	4.586

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8i) Experiment 2C: Accuracy data (2600 ms delay condition)

Descriptive Statistics

	Mean	Std. Deviation	N
R2600	89.0176	11.47166	34
F2600	93.3324	7.51030	34
D2600	90.5824	12.29004	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.945	1.825	2	.402	.947	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	324.445	2	162.222	2.245	.114
	Greenhouse-Geisser	324.445	1.895	171.213	2.245	.117
	Huynh-Feldt	324.445	2.000	162.222	2.245	.114
	Lower-bound	324.445	1.000	324.445	2.245	.144
Error(PROBE)	Sphericity Assumed	4769.968	66	72.272		
	Greenhouse-Geisser	4769.968	62.534	76.278		
	Huynh-Feldt	4769.968	66.000	72.272		
	Lower-bound	4769.968	33.000	144.544		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-4.315	2.158	.054	-8.706	.077
	3	-1.565	2.200	.482	-6.040	2.911
2	1	4.315	2.158	.054	-.077	8.706
	3	2.750	1.804	.137	-.921	6.421
3	1	1.565	2.200	.482	-2.911	6.040
	2	-2.750	1.804	.137	-6.421	.921

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes

(8j) Experiment 2C: Accuracy data (5200 ms delay condition)

Descriptive Statistics

	Mean	Std. Deviation	N
R5200	83.9176	11.14637	34
F5200	87.7471	9.79766	34
D5200	91.5676	11.16786	34

R = TBR probes, F = TBF probes, D = Control probes

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	.927	2.422	2	.298	.932	.986	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	994.883	2	497.441	4.713	.012
	Greenhouse-Geisser	994.883	1.864	533.701	4.713	.014
	Huynh-Feldt	994.883	1.971	504.667	4.713	.013
	Lower-bound	994.883	1.000	994.883	4.713	.037
Error(PROBE)	Sphericity Assumed	6965.397	66	105.536		
	Greenhouse-Geisser	6965.397	61.516	113.229		
	Huynh-Feldt	6965.397	65.055	107.069		
	Lower-bound	6965.397	33.000	211.073		

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	-3.829	2.378	.117	-8.668	1.009
	3	-7.650*	2.803	.010	-13.352	-1.948
2	1	3.829	2.378	.117	-1.009	8.668
	3	-3.821	2.261	.101	-8.421	.780
3	1	7.650*	2.803	.010	1.948	13.352
	2	3.821	2.261	.101	-.780	8.421

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes, 2 = TBF probes, 3 = Control probes

(9a) Experiment 3A: Response times data (between spatial proximity conditions)

Descriptive Statistics

	Mean	Std. Deviation	N
TBR_CL	1002,8235	374,11491	17
TBR_FAR	1085,5882	310,65024	17
TBF_CL	1146,0294	359,21796	17
TBF_FAR	757,7941	174,36394	17
C_RF_CL	1082,2647	333,68806	17
C_R_FAR	1355,0294	1046,14975	17
C_RF_CL1	1082,2647	333,68806	17
C_F_FAR	766,9412	229,38191	17
C_OUT_CL	765,6471	156,72505	17
C_OUT_FA	782,0000	138,73694	17

TBR_CL = TBR probes in the "close" condition
TBR_FAR = TBR probes in the "far" condition
TBF_CL = TBF probes in the "close" condition
TBF_FAR = TBF probes in the "far" condition
C_RF_CL/C_RF_CL1 (identical) = Control probes presented in the same cluster as TBR and TBF items in the "close" condition (presented twice to allow SPSS to compare these with (a) the control probes in the TBR cluster and (b) the control probes in the TBF cluster in the "far" condition)
C_R_FAR = Control probes presented in the same cluster as TBR items in the "far" condition
C_F_FAR = Control probes presented in the same cluster as TBF items in the "far" condition
C_OUT_CL = Control probes presented in a separate cluster in the "close" condition
C_OUT_FA = Control probes presented in a separate cluster in the "far" condition

Estimates

Measure: MEASURE_1

DISTANCE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1015,806	62,203	883,940	1147,671
2	949,471	66,073	809,401	1089,540

1 = "close" condition, 2 = "far" condition (irrespective of probe type)

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1044,206	81,310	871,835	1216,576
2	951,912	50,156	845,586	1058,238
3	1218,647	155,413	889,186	1548,108
4	924,603	57,018	803,730	1045,476
5	773,824	31,863	706,276	841,371

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	92,294	56,327	,121	-27,114	211,703
	3	-174,441	114,548	,147	-417,272	68,389
	4	119,603*	53,218	,039	6,786	232,420
	5	270,382*	78,953	,003	103,010	437,755
2	1	-92,294	56,327	,121	-211,703	27,114
	3	-266,735	136,387	,068	-555,862	22,392
	4	27,309	41,288	,518	-60,217	114,835
	5	178,088*	45,250	,001	82,164	274,013
3	1	174,441	114,548	,147	-68,389	417,272
	2	266,735	136,387	,068	-22,392	555,862
	4	294,044*	132,682	,042	12,770	575,318
	5	444,824*	156,790	,012	112,443	777,204
4	1	-119,603*	53,218	,039	-232,420	-6,786
	2	-27,309	41,288	,518	-114,835	60,217
	3	-294,044*	132,682	,042	-575,318	-12,770
	5	150,779*	44,259	,004	56,955	244,604
5	1	-270,382*	78,953	,003	-437,755	-103,010
	2	-178,088*	45,250	,001	-274,013	-82,164
	3	-444,824*	156,790	,012	-777,204	-112,443
	4	-150,779*	44,259	,004	-244,604	-56,955

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of probe types irrespective of spatial proximity. 1 = TBR probes, 2 = TBF probes, 3 = Control probes in the same cluster as TBR items, 4 = Control probes in the same cluster as TBF items, 5 = Control probes in a separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,026	52,841	9	,000	,363	,390	,250
DISTANCE	1,000	,000	0	.	1,000	1,000	1,000
PROBE * DISTANCE	,014	61,350	9	,000	,350	,373	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE+DISTANCE+PROBE*DISTANCE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	3651822,112	4	912955,528	5,846	,000
	Greenhouse-Geisser	3651822,112	1,451	2516493,546	5,846	,015
	Huynh-Feldt	3651822,112	1,558	2343654,640	5,846	,013
	Lower-bound	3651822,112	1,000	3651822,112	5,846	,028
Error(PROBE)	Sphericity Assumed	9994356,688	64	156161,823		
	Greenhouse-Geisser	9994356,688	23,218	430448,372		
	Huynh-Feldt	9994356,688	24,931	400884,129		
	Lower-bound	9994356,688	16,000	624647,293		
DISTANCE	Sphericity Assumed	187015,778	1	187015,778	3,893	,066
	Greenhouse-Geisser	187015,778	1,000	187015,778	3,893	,066
	Huynh-Feldt	187015,778	1,000	187015,778	3,893	,066
	Lower-bound	187015,778	1,000	187015,778	3,893	,066
Error(DISTANCE)	Sphericity Assumed	768577,947	16	48036,122		
	Greenhouse-Geisser	768577,947	16,000	48036,122		
	Huynh-Feldt	768577,947	16,000	48036,122		
	Lower-bound	768577,947	16,000	48036,122		
PROBE * DISTANCE	Sphericity Assumed	2632209,582	4	658052,396	5,429	,001
	Greenhouse-Geisser	2632209,582	1,398	1882557,749	5,429	,020
	Huynh-Feldt	2632209,582	1,491	1765537,738	5,429	,018
	Lower-bound	2632209,582	1,000	2632209,582	5,429	,033
Error(PROBE*DISTANCE)	Sphericity Assumed	7757398,818	64	121209,357		
	Greenhouse-Geisser	7757398,818	22,371	346755,995		
	Huynh-Feldt	7757398,818	23,854	325201,602		
	Lower-bound	7757398,818	16,000	484837,426		

(9b) Experiment 3A: Response times data in "close" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	994,3571	355,64446	21
TBF	1142,0000	397,95427	21
CONT_R_F	1083,0714	356,46715	21
CONT_OUT	762,9048	164,01613	21

CONT_R_F = Control probes presented in the same cluster as TBR and TBF items.
CONT_OUT – Control probes presented in a separate cluster

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,730	5,900	5	,317	,851	,987	,333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	1747889,393	3	582629,798	11,624	,000
	Greenhouse-Geisser	1747889,393	2,554	684300,333	11,624	,000
	Huynh-Feldt	1747889,393	2,960	590499,004	11,624	,000
	Lower-bound	1747889,393	1,000	1747889,393	11,624	,003
Error(PROBE)	Sphericity Assumed	3007314,357	60	50121,906		
	Greenhouse-Geisser	3007314,357	51,085	58868,319		
	Huynh-Feldt	3007314,357	59,200	50798,870		
	Lower-bound	3007314,357	20,000	150365,718		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-147,643*	62,526	,028	-278,070	-17,216
	3	-88,714	49,710	,089	-192,407	14,979
	4	231,452*	79,239	,008	66,163	396,742
2	1	147,643*	62,526	,028	17,216	278,070
	3	58,929	67,971	,396	-82,857	200,714
	4	379,095*	78,723	,000	214,882	543,308
3	1	88,714	49,710	,089	-14,979	192,407
	2	-58,929	67,971	,396	-200,714	82,857
	4	320,167*	71,863	,000	170,263	470,070
4	1	-231,452*	79,239	,008	-396,742	-66,163
	2	-379,095*	78,723	,000	-543,308	-214,882
	3	-320,167*	71,863	,000	-470,070	-170,263

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes, 2 = TBF probes, 3 = Control probes presented in the same cluster as TBR and TBF items, 4 = Control probes presented in a separate cluster.

(9c) Experiment 3A: Response times data in "far" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	1085,5882	310,65024	17
TBF	757,7941	174,36394	17
CONT_TBR	1355,0294	1046,14975	17
CONT_TBF	766,9412	229,38191	17
CONT_OUT	782,0000	138,73694	17

CONT_TBR = Control probes presented in the same cluster as TBR items, CONT_TBF = Control probes presented in the same cluster as TBF items, CONT_OUT = Control probes presented in a separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,001	101,096	9	,000	,282	,288	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	4778856,853	4	1194714,213	5,182	,001
	Greenhouse-Geisser	4778856,853	1,127	4240945,162	5,182	,032
	Huynh-Feldt	4778856,853	1,154	4142907,219	5,182	,031
	Lower-bound	4778856,853	1,000	4778856,853	5,182	,037
Error(PROBE)	Sphericity Assumed	14753838,2	64	230528,723		
	Greenhouse-Geisser	14753838,2	18,029	818320,951		
	Huynh-Feldt	14753838,2	18,456	799403,823		
	Lower-bound	14753838,2	16,000	922114,890		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	327,794*	74,844	,000	169,133	486,455
	3	-269,441	214,237	,227	-723,604	184,722
	4	318,647*	75,082	,001	159,481	477,813
	5	303,588*	69,579	,000	156,088	451,089
2	1	-327,794*	74,844	,000	-486,455	-169,133
	3	-597,235*	258,472	,035	-1145,172	-49,299
	4	-9,147	44,019	,838	-102,463	84,169
	5	-24,206	27,396	,390	-82,283	33,872
3	1	269,441	214,237	,227	-184,722	723,604
	2	597,235*	258,472	,035	49,299	1145,172
	4	588,088*	265,365	,042	25,540	1150,637
	5	573,029*	260,216	,043	21,397	1124,662
4	1	-318,647*	75,082	,001	-477,813	-159,481
	2	9,147	44,019	,838	-84,169	102,463
	3	-588,088*	265,365	,042	-1150,637	-25,540
	5	-15,059	40,071	,712	-100,006	69,889
5	1	-303,588*	69,579	,000	-451,089	-156,088
	2	24,206	27,396	,390	-33,872	82,283
	3	-573,029*	260,216	,043	-1124,662	-21,397
	4	15,059	40,071	,712	-69,889	100,006

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes, 2 = TBF probes, 3 = Control probes presented in the same cluster as TBR items, 4 = Control probes presented in the same cluster as TBF items, 5 = Control probes presented in separate cluster.

(9d) Experiment 3A: Accuracy data (between spatial proximity conditions)

Descriptive Statistics

	Mean	Std. Deviation	N
TBR_CL	61,5952	16,98875	21
TBR_FAR	70,1762	19,50502	21
TBF_CL	55,5381	17,29634	21
TBF_FAR	91,7381	12,97415	21
C_RF_CL	61,9048	21,82179	21
C_R_FAR	36,1905	25,78298	21
C_RF_CL1	61,9048	21,82179	21
C_F_FAR	94,2857	11,21224	21
C_OUT_CL	99,0476	4,36436	21
C_OUT_FA	91,4286	10,14185	21

TBR_CL = TBR probes in the "close" condition
TBR_FAR = TBR probes in the "far" condition
TBF_CL = TBF probes in the "close" condition
TBF_FAR = TBF probes in the "far" condition
C_RF_CL/C_RF_CL1 (identical) = Control probes presented in the same cluster as TBR and TBF items in the "close" condition (presented twice to allow SPSS to compare these with (a) the control probes in the TBR cluster and (b) the control probes in the TBF cluster in the "far" condition)
C_R_FAR = Control probes presented in the same cluster as TBR items in the "far" condition
C_F_FAR = Control probes presented in the same cluster as TBF items in the "far" condition
C_OUT_CL = Control probes presented in a separate cluster in the "close" condition
C_OUT_FA = Control probes presented in a separate cluster in the "far" condition.

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
DISTANCE	Mean	Std. Error	Lower Bound	Upper Bound
1	67,998	2,246	63,313	72,683
2	76,764	1,806	72,996	80,532

1 = "close" condition, 2 = "far" condition (irrespective of probe types)

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
PROBE	Mean	Std. Error	Lower Bound	Upper Bound
1	65,886	2,945	59,743	72,028
2	73,638	2,730	67,944	79,332
3	49,048	4,359	39,955	58,141
4	78,095	2,855	72,139	84,051
5	95,238	1,313	92,500	97,976

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-7,752	4,219	,081	-16,552	1,047
	3	16,838*	6,372	,016	3,545	30,131
	4	-12,210*	4,454	,013	-21,500	-2,919
	5	-29,352*	3,493	,000	-36,639	-22,066
2	1	7,752	4,219	,081	-1,047	16,552
	3	24,590*	3,451	,000	17,393	31,788
	4	-4,457	2,405	,079	-9,474	,559
	5	-21,600*	2,727	,000	-27,288	-15,912
3	1	-16,838*	6,372	,016	-30,131	-3,545
	2	-24,590*	3,451	,000	-31,788	-17,393
	4	-29,048*	2,920	,000	-35,139	-22,957
	5	-46,190*	4,253	,000	-55,061	-37,320
4	1	12,210*	4,454	,013	2,919	21,500
	2	4,457	2,405	,079	-,559	9,474
	3	29,048*	2,920	,000	22,957	35,139
	5	-17,143*	2,939	,000	-23,274	-11,012
5	1	29,352*	3,493	,000	22,066	36,639
	2	21,600*	2,727	,000	15,912	27,288
	3	46,190*	4,253	,000	37,320	55,061
	4	17,143*	2,939	,000	11,012	23,274

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of probe types irrespective of spatial proximity. 1 = TBR probes, 2 = TBF probes, 3 = Control probes in the same cluster as TBR items, 4 = Control probes in the same cluster as TBF items, 5 = Control probes in a separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,147	35,369	9	,000	,464	,510	,250
DISTANCE	1,000	,000	0	.	1,000	1,000	1,000
PROBE * DISTANCE	,340	19,857	9	,019	,692	,814	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE+DISTANCE+PROBE*DISTANCE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	48019,230	4	12004,808	37,905	,000
	Greenhouse-Geisser	48019,230	1,857	25863,850	37,905	,000
	Huynh-Feldt	48019,230	2,039	23553,840	37,905	,000
	Lower-bound	48019,230	1,000	48019,230	37,905	,000
Error(PROBE)	Sphericity Assumed	25336,884	80	316,711		
	Greenhouse-Geisser	25336,884	37,132	682,341		
	Huynh-Feldt	25336,884	40,774	621,398		
	Lower-bound	25336,884	20,000	1266,844		
DISTANCE	Sphericity Assumed	4033,982	1	4033,982	16,195	,001
	Greenhouse-Geisser	4033,982	1,000	4033,982	16,195	,001
	Huynh-Feldt	4033,982	1,000	4033,982	16,195	,001
	Lower-bound	4033,982	1,000	4033,982	16,195	,001
Error(DISTANCE)	Sphericity Assumed	4981,624	20	249,081		
	Greenhouse-Geisser	4981,624	20,000	249,081		
	Huynh-Feldt	4981,624	20,000	249,081		
	Lower-bound	4981,624	20,000	249,081		
PROBE * DISTANCE	Sphericity Assumed	29060,687	4	7265,172	33,703	,000
	Greenhouse-Geisser	29060,687	2,766	10504,627	33,703	,000
	Huynh-Feldt	29060,687	3,255	8927,916	33,703	,000
	Lower-bound	29060,687	1,000	29060,687	33,703	,000
Error(PROBE*DISTANCE)	Sphericity Assumed	17245,287	80	215,566		
	Greenhouse-Geisser	17245,287	55,329	311,684		
	Huynh-Feldt	17245,287	65,101	264,902		
	Lower-bound	17245,287	20,000	862,264		

(9e) Experiment 3A: Accuracy data in the "close" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	61,5952	16,98875	21
TBF	55,5381	17,29634	21
CONT_R_F	61,9048	21,82179	21
CONT_OUT	99,0476	4,36436	21

CONT_R_F = Control probes presented in the same cluster as TBR and TBF items.
CONT_OUT – Control probes presented in a separate cluster

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,294	22,942	5	,000	,579	,629	,333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	24951,520	3	8317,173	30,608	,000
	Greenhouse-Geisser	24951,520	1,736	14372,110	30,608	,000
	Huynh-Feldt	24951,520	1,887	13225,046	30,608	,000
	Lower-bound	24951,520	1,000	24951,520	30,608	,000
Error(PROBE)	Sphericity Assumed	16303,890	60	271,731		
	Greenhouse-Geisser	16303,890	34,722	469,553		
	Huynh-Feldt	16303,890	37,734	432,077		
	Lower-bound	16303,890	20,000	815,194		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	6,057	6,103	,333	-6,673	18,787
	3	-,310	7,076	,966	-15,070	14,451
	4	-37,452*	3,638	,000	-45,040	-29,864
2	1	-6,057	6,103	,333	-18,787	6,673
	3	-6,367	4,048	,131	-14,811	2,077
	4	-43,510*	3,865	,000	-51,572	-35,447
3	1	,310	7,076	,966	-14,451	15,070
	2	6,367	4,048	,131	-2,077	14,811
	4	-37,143*	4,837	,000	-47,234	-27,052
4	1	37,452*	3,638	,000	29,864	45,040
	2	43,510*	3,865	,000	35,447	51,572
	3	37,143*	4,837	,000	27,052	47,234

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes, 2 = TBF probes, 3 = Control probes presented in the same cluster as TBR and TBF items, 4 = Control probes presented in a separate cluster.

(9f) Experiment 3A: Accuracy data in the "far" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	70,1762	19,50502	21
TBF	91,7381	12,97415	21
CONT_TBR	36,1905	25,78298	21
CONT_TBF	94,2857	11,21224	21
CONT_OUT	91,4286	10,14185	21

CONT_TBR = Control probes presented in the same cluster as TBR items, CONT_TBF = Control probes presented in the same cluster as TBF items, CONT_OUT = Control probes presented in a separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,138	36,409	9	,000	,486	,537	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	51153,768	4	12788,442	46,523	,000
	Greenhouse-Geisser	51153,768	1,943	26325,141	46,523	,000
	Huynh-Feldt	51153,768	2,149	23802,270	46,523	,000
	Lower-bound	51153,768	1,000	51153,768	46,523	,000
Error(PROBE)	Sphericity Assumed	21990,964	80	274,887		
	Greenhouse-Geisser	21990,964	38,863	565,858		
	Huynh-Feldt	21990,964	42,982	511,629		
	Lower-bound	21990,964	20,000	1099,548		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-21,562*	4,504	,000	-30,958	-12,166
	3	33,986*	8,368	,001	16,531	51,441
	4	-24,110*	4,127	,000	-32,718	-15,501
	5	-21,252*	5,197	,001	-32,093	-10,412
2	1	21,562*	4,504	,000	12,166	30,958
	3	55,548*	5,827	,000	43,393	67,702
	4	-2,548	2,816	,376	-8,423	3,327
	5	,310	2,700	,910	-5,323	5,942
3	1	-33,986*	8,368	,001	-51,441	-16,531
	2	-55,548*	5,827	,000	-67,702	-43,393
	4	-58,095*	5,840	,000	-70,277	-45,913
	5	-55,238*	5,840	,000	-67,420	-43,056
4	1	24,110*	4,127	,000	15,501	32,718
	2	2,548	2,816	,376	-3,327	8,423
	3	58,095*	5,840	,000	45,913	70,277
	5	2,857	3,173	,379	-3,762	9,476
5	1	21,252*	5,197	,001	10,412	32,093
	2	-,310	2,700	,910	-5,942	5,323
	3	55,238*	5,840	,000	43,056	67,420
	4	-2,857	3,173	,379	-9,476	3,762

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes, 2 = TBF probes, 3 = Control probes presented in the same cluster as TBR items, 4 = Control probes presented in the same cluster as TBF items, 5 = Control probes presented in separate cluster.

(10a) Experiment 3B: Response times (between spatial proximity conditions)

Descriptive Statistics

	Mean	Std. Deviation	N
CL_TBR	962,0217	286,43881	23
FAR_TBR	953,9348	277,90193	23
CL_TBF	979,8478	302,99604	23
FAR_TBF	831,1304	305,30541	23
CL_C_RF1	874,3043	285,41006	23
FAR_C_R	1013,3913	277,09077	23
CL_C_RF2	874,3043	285,41006	23
FAR_C_F	899,9348	312,38643	23
CL_C_OUT	856,3696	306,91079	23
FAR_COUT	837,1522	293,65133	23

CL_TBR = TBR probes in the "close" condition
FAR_TBR = TBR probes in the "far" condition
CL_TBF = TBF probes in the "close" condition
FAR_TBF = TBF probes in the "far" condition
CL_C_RF1 + CL_C_RF2 (identical) = Control probes located in the same cluster as TBR and TBF items in the "close" condition (this was presented twice in SPSS to allow the program to compare it with the control probes presented in the same cluster as the TBR set and with control probes presented in the same cluster as the TBF set in the "far" condition)
FAR_C_R = Control probes located in the same cluster as TBR items in the "far" condition.
FAR_C_F = Control probes located in the same cluster as TBF items in the "far" condition.
CL_C_OUT = Control probes located in separate cluster in the "close" condition.
FAR_C_OUT = Control probes located in separate cluster in the "far" condition.

Estimates

Measure: MEASURE_1

DISTANCE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	909,370	56,746	791,686	1027,053
2	907,109	54,744	793,577	1020,640

1 = Close condition, 2 = Far condition (irrespective of probe types)

Estimates

Measure: MEASURE_1

PROBE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	957,978	56,584	840,631	1075,325
2	905,489	60,031	780,993	1029,985
3	943,848	53,355	833,196	1054,499
4	887,120	58,342	766,127	1008,113
5	846,761	59,433	723,503	970,018

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	52,489*	25,099	,048	,438	104,541
	3	14,130	23,958	,561	-35,556	63,817
	4	70,859*	30,284	,029	8,054	133,663
	5	111,217*	36,994	,006	34,496	187,939
2	1	-52,489*	25,099	,048	-104,541	-,438
	3	-38,359	27,741	,181	-95,891	19,174
	4	18,370	22,962	,432	-29,250	65,989
	5	58,728*	26,956	,040	2,825	114,631
3	1	-14,130	23,958	,561	-63,817	35,556
	2	38,359	27,741	,181	-19,174	95,891
	4	56,728	28,703	,061	-2,799	116,255
	5	97,087*	30,512	,004	33,809	160,365
4	1	-70,859*	30,284	,029	-133,663	-8,054
	2	-18,370	22,962	,432	-65,989	29,250
	3	-56,728	28,703	,061	-116,255	2,799
	5	40,359	24,854	,119	-11,186	91,903
5	1	-111,217*	36,994	,006	-187,939	-34,496
	2	-58,728*	26,956	,040	-114,631	-2,825
	3	-97,087*	30,512	,004	-160,365	-33,809
	4	-40,359	24,854	,119	-91,903	11,186

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of probe types, irrespective of spatial proximity. 1 = TBR probe, 2 = TBF probe, 3 = Control probe in TBR cluster, 4 = Control probe in TBF cluster, 5 = Control probe in separate cluster.

Mauchly's Test of Sphericity

Measure: MEASURE_1

Within Subjects Effec	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,529	13,014	9	,163	,751	,883	,250
DISTANCE	1,000	,000	0	.	1,000	1,000	1,000
PROBE * DISTANCE	,458	15,940	9	,069	,707	,823	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed Tests of Within-Subjects Effects table.

b.

Design: Intercept

Within Subjects Design: PROBE+DISTANCE+PROBE*DISTANCE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	366856,228	4	91714,057	5,057	,001
	Greenhouse-Geisser	366856,228	3,005	122074,605	5,057	,003
	Huynh-Feldt	366856,228	3,534	103820,856	5,057	,002
	Lower-bound	366856,228	1,000	366856,228	5,057	,035
Error(PROBE)	Sphericity Assumed	1596063,322	88	18137,083		
	Greenhouse-Geisser	1596063,322	66,114	24141,090		
	Huynh-Feldt	1596063,322	77,738	20531,286		
	Lower-bound	1596063,322	22,000	72548,333		
DISTANCE	Sphericity Assumed	293,913	1	293,913	,012	,914
	Greenhouse-Geisser	293,913	1,000	293,913	,012	,914
	Huynh-Feldt	293,913	1,000	293,913	,012	,914
	Lower-bound	293,913	1,000	293,913	,012	,914
Error(DISTANCE)	Sphericity Assumed	537738,437	22	24442,656		
	Greenhouse-Geisser	537738,437	22,000	24442,656		
	Huynh-Feldt	537738,437	22,000	24442,656		
	Lower-bound	537738,437	22,000	24442,656		
PROBE * DISTANCE	Sphericity Assumed	489073,293	4	122268,323	6,565	,000
	Greenhouse-Geisser	489073,293	2,829	172864,191	6,565	,001
	Huynh-Feldt	489073,293	3,290	148653,155	6,565	,000
	Lower-bound	489073,293	1,000	489073,293	6,565	,018
Error(PROBE*DISTANCE)	Sphericity Assumed	1639055,857	88	18625,635		
	Greenhouse-Geisser	1639055,857	62,243	26333,111		
	Huynh-Feldt	1639055,857	72,381	22644,944		
	Lower-bound	1639055,857	22,000	74502,539		

(10b) Experiment 3B: Response times in "close" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	962,0217	288,43881	23
TBF	979,8478	302,99604	23
CONT_R_F	874,3043	285,41006	23
CONT_OUT	856,3696	306,91079	23

CONT_R_F = Control probe presented in the same cluster as the TBR and TBF items, CONT_OUT – Control probe presented in a separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,496	14,513	5	,013	,715	,795	,333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	263824,117	3	87941,372	4,770	,005
	Greenhouse-Geisser	263824,117	2,145	122976,085	4,770	,011
	Huynh-Feldt	263824,117	2,384	110643,389	4,770	,009
	Lower-bound	263824,117	1,000	263824,117	4,770	,040
Error(PROBE)	Sphericity Assumed	1216888,071	66	18437,698		
	Greenhouse-Geisser	1216888,071	47,197	25783,040		
	Huynh-Feldt	1216888,071	52,458	23197,380		
	Lower-bound	1216888,071	22,000	55313,094		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-17,826	34,324	,609	-89,009	53,357
	3	87,717*	32,428	,013	20,466	154,969
	4	105,652*	50,636	,049	,640	210,665
2	1	17,826	34,324	,609	-53,357	89,009
	3	105,543*	38,308	,012	26,097	184,990
	4	123,478*	48,079	,018	23,768	223,188
3	1	-87,717*	32,428	,013	-154,969	-20,466
	2	-105,543*	38,308	,012	-184,990	-26,097
	4	17,935	32,355	,585	-49,166	85,036
4	1	-105,652*	50,636	,049	-210,665	-,640
	2	-123,478*	48,079	,018	-223,188	-23,768
	3	-17,935	32,355	,585	-85,036	49,166

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes presented in the same cluster as TBR and TBF items.
4 = Control probes presented in separate cluster.

(10c) Experiment 3B: Response times in "far" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	953,9348	277,90193	23
TBF	831,1304	305,30541	23
CONT_TBR	1013,3913	277,09077	23
CONT_TBF	899,9348	312,38643	23
CONT_OUT	837,1522	293,65133	23

CONT_R = Control probe presented in the same cluster as the TBR items, CONT_F = Control probe presented in the same cluster as the TBF items, CONT_OUT = Control probe presented in a separate cluster.

Mauchly's Test of Sphericity [b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon [a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,284	25,719	9	,002	,680	,786	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	556755,283	4	139188,821	6,444	,000
	Greenhouse-Geisser	556755,283	2,722	204572,287	6,444	,001
	Huynh-Feldt	556755,283	3,143	177130,590	6,444	,001
	Lower-bound	556755,283	1,000	556755,283	6,444	,019
Error(PROBE)	Sphericity Assumed	1900732,817	88	21599,237		
	Greenhouse-Geisser	1900732,817	59,874	31745,403		
	Huynh-Feldt	1900732,817	69,150	27487,017		
	Lower-bound	1900732,817	22,000	86396,946		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig. [a]	95% Confidence Interval for Difference [a]	
					Lower Bound	Upper Bound
1	2	122,804*	33,431	,001	53,472	192,136
	3	-59,457	45,852	,208	-154,548	35,635
	4	54,000	41,512	,207	-32,091	140,091
	5	116,783*	44,233	,015	25,049	208,517
2	1	-122,804*	33,431	,001	-192,136	-53,472
	3	-182,261*	54,452	,003	-295,188	-69,333
	4	-68,804*	30,772	,036	-132,621	-4,988
	5	-6,022	30,056	,843	-68,354	56,311
3	1	59,457	45,852	,208	-35,635	154,548
	2	182,261*	54,452	,003	69,333	295,188
	4	113,457	57,407	,061	-5,597	232,510
	5	176,239*	45,006	,001	82,901	269,577
4	1	-54,000	41,512	,207	-140,091	32,091
	2	68,804*	30,772	,036	4,988	132,621
	3	-113,457	57,407	,061	-232,510	5,597
	5	62,783	41,781	,147	-23,866	149,431
5	1	-116,783*	44,233	,015	-208,517	-25,049
	2	6,022	30,056	,843	-56,311	68,354
	3	-176,239*	45,006	,001	-269,577	-82,901
	4	-62,783	41,781	,147	-149,431	23,866

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes, 2 = TBF probes, 3 = Control probes presented in the same cluster as TBR items., 4 = Control probes presented in the same cluster as TBF items, 5 = Control probes presented in separate cluster.

(10d) Experiment 3B: Accuracy data (between spatial proximity conditions)

Descriptive Statistics

	Mean	Std. Deviation	N
CL_TBR	80,5783	12,69115	23
FAR_TBR	84,0130	15,78052	23
CL_TBF	80,5739	15,29837	23
FAR_TBF	91,3043	12,29107	23
CL_C_RF1	85,6522	16,18812	23
FAR_C_R	74,7826	19,27541	23
CL_C_RF2	85,6522	16,18812	23
FAR_C_F	96,5217	9,82052	23
CL_C_OUT	97,3913	6,88700	23
FAR_COUT	92,1739	15,65437	23

CL_TBR = TBR probes in the "close" condition
FAR_TBR = TBR probes in the "far" condition
CL_TBF = TBF probes in the "close" condition
FAR_TBF = TBF probes in the "far" condition
CL_C_RF1 + CL_C_RF2 (identical) = Control probes located in the same cluster as TBR and TBF items in the "close" condition (this was presented twice in SPSS to allow the program to compare it with the control probes presented in the same cluster as the TBR set and with control probes presented in the same cluster as the TBF set in the "far" condition)
FAR_C_R = Control probes located in the same cluster as TBR items in the "far" condition.
FAR_C_F = Control probes located in the same cluster as TBF items in the "far" condition.
CL_C_OUT = Control probes located in separate cluster in the "close" condition.
FAR_C_OUT = Control probes located in separate cluster in the "far" condition.

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
DISTANCE	Mean	Std. Error	Lower Bound	Upper Bound
1	85,970	1,893	82,044	89,895
2	87,759	1,853	83,917	91,602

1 = "close" condition, 2 = "far" condition.

Estimates

Measure: MEASURE_1

			95% Confidence Interval	
PROBE	Mean	Std. Error	Lower Bound	Upper Bound
1	82,296	2,788	76,515	88,077
2	85,939	2,549	80,653	91,225
3	80,217	3,023	73,948	86,487
4	91,087	2,177	86,572	95,602
5	94,783	1,975	90,687	98,879

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-3,643	2,441	,150	-8,706	1,419
	3	2,078	4,435	,644	-7,119	11,275
	4	-8,791*	3,793	,030	-16,658	-,924
	5	-12,487*	3,570	,002	-19,890	-5,084
2	1	3,643	2,441	,150	-1,419	8,706
	3	5,722	3,227	,090	-,971	12,414
	4	-5,148	2,546	,055	-10,427	,131
	5	-8,843*	2,846	,005	-14,746	-2,941
3	1	-2,078	4,435	,644	-11,275	7,119
	2	-5,722	3,227	,090	-12,414	,971
	4	-10,870*	1,979	,000	-14,975	-6,764
	5	-14,565*	2,897	,000	-20,573	-8,558
4	1	8,791*	3,793	,030	,924	16,658
	2	5,148	2,546	,055	-,131	10,427
	3	10,870*	1,979	,000	6,764	14,975
	5	-3,696	2,183	,105	-8,222	,831
5	1	12,487*	3,570	,002	5,084	19,890
	2	8,843*	2,846	,005	2,941	14,746
	3	14,565*	2,897	,000	8,558	20,573
	4	3,696	2,183	,105	-,831	8,222

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Comparison of probe types, irrespective of spatial proximity. 1 = TBR probe, 2 = TBF probe, 3 = Control probe in TBR cluster, 4 = Control probe in TBF cluster, 5 = Control probe in separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,230	29,985	9	,000	,558	,624	,250
DISTANCE	1,000	,000	0	.	1,000	1,000	1,000
PROBE * DISTANCE	,683	7,784	9	,557	,858	1,000	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept

Within Subjects Design: PROBE+DISTANCE+PROBE*DISTANCE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	6736,255	4	1684,064	7,722	,000
	Greenhouse-Geisser	6736,255	2,233	3016,150	7,722	,001
	Huynh-Feldt	6736,255	2,498	2697,145	7,722	,000
	Lower-bound	6736,255	1,000	6736,255	7,722	,011
Error(PROBE)	Sphericity Assumed	19192,513	88	218,097		
	Greenhouse-Geisser	19192,513	49,135	390,610		
	Huynh-Feldt	19192,513	54,946	349,297		
	Lower-bound	19192,513	22,000	872,387		
DISTANCE	Sphericity Assumed	184,146	1	184,146	,897	,354
	Greenhouse-Geisser	184,146	1,000	184,146	,897	,354
	Huynh-Feldt	184,146	1,000	184,146	,897	,354
	Lower-bound	184,146	1,000	184,146	,897	,354
Error(DISTANCE)	Sphericity Assumed	4514,790	22	205,218		
	Greenhouse-Geisser	4514,790	22,000	205,218		
	Huynh-Feldt	4514,790	22,000	205,218		
	Lower-bound	4514,790	22,000	205,218		
PROBE * DISTANCE	Sphericity Assumed	4306,098	4	1076,525	10,752	,000
	Greenhouse-Geisser	4306,098	3,433	1254,301	10,752	,000
	Huynh-Feldt	4306,098	4,000	1076,525	10,752	,000
	Lower-bound	4306,098	1,000	4306,098	10,752	,003
Error(PROBE*DISTANCE)	Sphericity Assumed	8810,986	88	100,125		
	Greenhouse-Geisser	8810,986	75,527	116,659		
	Huynh-Feldt	8810,986	88,000	100,125		
	Lower-bound	8810,986	22,000	400,499		

(10e): Experiment 3B: Accuracy data in the "close" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	80,5783	12,69115	23
TBF	80,5739	15,29837	23
CONT_R_F	85,6522	16,18812	23
CONT_OUT	97,3913	6,88700	23

CONT_R_F = Control probe presented in the same cluster as the TBR and TBF items, CONT_OUT – Control probe presented in a separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,596	10,710	5	,058	,767	,861	,333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	4340,351	3	1446,784	9,925	,000
	Greenhouse-Geisser	4340,351	2,300	1886,982	9,925	,000
	Huynh-Feldt	4340,351	2,584	1679,730	9,925	,000
	Lower-bound	4340,351	1,000	4340,351	9,925	,005
Error(PROBE)	Sphericity Assumed	9621,287	66	145,777		
	Greenhouse-Geisser	9621,287	50,603	190,131		
	Huynh-Feldt	9621,287	56,847	169,249		
	Lower-bound	9621,287	22,000	437,331		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	4,348E-03	3,482	,999	-7,216	7,225
	3	-5,074	4,647	,287	-14,711	4,563
	4	-16,813*	2,898	,000	-22,823	-10,803
2	1	-4,348E-03	3,482	,999	-7,225	7,216
	3	-5,078	3,402	,150	-12,134	1,978
	4	-16,817*	3,323	,000	-23,709	-9,926
3	1	5,074	4,647	,287	-4,563	14,711
	2	5,078	3,402	,150	-1,978	12,134
	4	-11,739*	3,365	,002	-18,718	-4,760
4	1	16,813*	2,898	,000	10,803	22,823
	2	16,817*	3,323	,000	9,926	23,709
	3	11,739*	3,365	,002	4,760	18,718

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes
2 = TBF probes
3 = Control probes presented in the same cluster as TBR and TBF items.
4 = Control probes presented in separate cluster.

(10f) Experiment 3B: Accuracy data in the "far" condition

Descriptive Statistics

	Mean	Std. Deviation	N
TBR	84,0130	15,78052	23
TBF	91,3043	12,29107	23
CONT_TBR	74,7826	19,27541	23
CONT_TBF	96,5217	9,82052	23
CONT_OUT	92,1739	15,65437	23

CONT_R = Control probe presented in the same cluster as the TBR items, CONT_F = Control probe presented in the same cluster as the TBF items, CONT_OUT = Control probe presented in a separate cluster.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
PROBE	,250	28,310	9	,001	,613	,696	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: PROBE

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PROBE	Sphericity Assumed	6699,106	4	1674,776	9,326	,000
	Greenhouse-Geisser	6699,106	2,453	2731,065	9,326	,000
	Huynh-Feldt	6699,106	2,784	2406,363	9,326	,000
	Lower-bound	6699,106	1,000	6699,106	9,326	,006
Error(PROBE)	Sphericity Assumed	15803,518	88	179,585		
	Greenhouse-Geisser	15803,518	53,964	292,851		
	Huynh-Feldt	15803,518	61,246	258,033		
	Lower-bound	15803,518	22,000	718,342		

Pairwise Comparisons

Measure: MEASURE_1

(I) PROBE	(J) PROBE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-7,291*	2,387	,006	-12,242	-2,341
	3	9,230	5,301	,096	-1,763	20,223
	4	-12,509*	3,963	,005	-20,727	-4,290
	5	-8,161	4,865	,108	-18,251	1,929
2	1	7,291*	2,387	,006	2,341	12,242
	3	16,522*	4,530	,001	7,127	25,917
	4	-5,217	2,869	,083	-11,167	,732
	5	-,870	4,002	,830	-9,170	7,431
3	1	-9,230	5,301	,096	-20,223	1,763
	2	-16,522*	4,530	,001	-25,917	-7,127
	4	-21,739*	3,959	,000	-29,949	-13,529
	5	-17,391*	3,835	,000	-25,345	-9,437
4	1	12,509*	3,963	,005	4,290	20,727
	2	5,217	2,869	,083	-,732	11,167
	3	21,739*	3,959	,000	13,529	29,949
	5	4,348	2,799	,135	-1,458	10,153
5	1	8,161	4,865	,108	-1,929	18,251
	2	,870	4,002	,830	-7,431	9,170
	3	17,391*	3,835	,000	9,437	25,345
	4	-4,348	2,799	,135	-10,153	1,458

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

1 = TBR probes, 2 = TBF probes, 3 = Control probes presented in the same cluster as TBR items., 4 = Control probes presented in the same cluster as TBF items, 5 = Control probes presented in separate cluster.

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