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MECHANISMS OF SHORT-TERM FALSE MEMORY FORMATION
KISA SÜRELİ SAHTE BELLEK FORMASYONLARININ MEKANİZMALARI

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Summary

False memories are the erroneous recollection of events that did not actually occur. False memories have been broadly investigated within the domain of long-term memory, while studies involving short-term memory are less common and provide a far less detailed 'picture' of this phenomenon. We tested participants in a short-term memory task involving lists of four semantically related words that had to be matched with a probe word. Crucially, the probe word could be one of the four words of the list, it could be semantically related to them, or it could be semantically unrelated to the list. Participants had to decide whether the probe was in the list. To this task we added articulatory suppression to impair rehearsal, concurrent material to remember, and changes to the visual appearance of the probes to assess the mechanism involved in short-term memory retrieval. The results showed that, similarly to the studies on long-term memory, false memories emerged more frequently for probes semantically related to the list and when rehearsal was impaired by concurrent material. The visual appearance of the stimuli did not play an important role. This set of results suggests that deep semantic processing, rather than only superficial visual processing, is taking place within a few seconds from the presentation of the probes.

Keywords: false memories; short-term memory; consciousness; semantic processing.

Özet

Sahte anılar aslında meydana gelmemiş/yaşanmamış olayların hatalı bir şekilde hatırlanmasıdır. Kısa süreli belleği içeren çalışmalar daha az yaygın ve bu fenomenin çok daha az detaylı bir "resmini" ortaya koymaktayken, sahte anılar uzun süreli belleğin alanı içerisinde geniş kapsamda araştırılmıştır. Çalışma kapsamında, katılımcıları birbiriyle semantik olarak ilişkili ve araştırılan kelime ile eşleştirilme zorunluluğu olan dört kelimelik listeleri içeren bir kısa süreli hafıza görevi ile test ettik. Kritik olarak, araştırılan kelime listedeki dört kelimeden biri, listedeki kelimelerle semantik olarak ilişkili, ya da listedeki kelimelerle semantik olarak ilişkisiz olabilirdi. Katılımcıların araştırılan kelimenin listede olup olmadığına karar vermeleri gerekmekteydi. Bu ödeve, kısa süreli bellekten geri çağırma mekanizmasını değerlendirmek için tekrarlamayı/prova etmeyi bozacak fonolojik baskılama, hatırlamayı eşzamanlı materyal ve araştırılan kelimenin görsel görünümüne değişiklikler ekledik. Sonuçlar, uzun süreli bellek çalışmalarına benzer şekilde, tekrarlama eşzamanlı materyallerle bozulduğunda ve araştırılan kelimeler listeyle semantik olarak ilişkili olduğunda sahte anıların daha sıklıkla ortaya çıktığını göstermiştir. Uyaranın görsel görünümünün önemli bir rolü yoktur. Bu sonuçlar kümesi, yüzeysel görsel süreçler yerine, derin semantik işlemenin araştırılan kelimelerin gösterilmesinden sonraki birkaç saniye içerisinde gerçekleştiğini göstermektedir.

Anahtar Kelimeler: sahte anlılar, kısa süreli bellek, bilinç , semantik işleme

1. Introduction

Memory can be fallible. Information in long-term memory (LTM) can either be successfully recalled or forgotten. Besides failing to remember events that actually occurred, two interesting errors can arise during recall or recognition: remembering events that did not happen or remembering them differently (Clancy et al., 2002; Loftus, 1996). In particular, a class of the former is referred to as 'false memories' (Deese, 1959; Jou & Flores, 2013; Pasqualotto et al., 2013; Robinson & Roediger, 1997; Roediger & Mcdermott, 1995; Roediger et al., 2001). Theories of false memory generally consider LTM, including associative activation or source monitoring failures (Collins & Loftus, 1975; Flegal et al., 2010; Quillian, 1967). False long-term memories are reliably produced with the Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & Mcdermott, 1995).

In classic DRM experiments, participants listen to lists of words semantically related to a single non-studied theme, or 'related lure' (e.g Roediger et al., 2001). For example, participants may hear (or read): *thread, pin, eye, etc.,* all semantically associated to the related lure needle. Then participants attempt to recall the list, usually through a free-recall or a recognition test, which includes studied words, non-studied related words and non-studied unrelated words. The results from most DRM experiments (e.g. Roediger & Mcdermott, 1995) demonstrate that participants falsely recall non-studied related words. Moreover Roediger and colleagues found that confidence ratings, or remember-know (where 'remember' entails that an individual can consciously remember the occurrence of an episode, or whether s/he can only vaguely 'know' that it happened), indicate that participants are fairly confident in recognizing the non-studied related word as a studied word (Rajaram & Roediger, 1997).

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Although the majority of research on false memory has been focused on LTM, research on short-term memory (STM) illustrates that this system is also vulnerable to various interferences such as phonological and visual similarity (Nairne, 2002; Neath, 2000). Recent studies have established that robust false memories also exist in STM (Atkins & Reuter-Lorenz, 2008; Coane et al., 2007; Flegal, et al., 2010). These findings indicate that the mechanisms underlying false memories formation might be delay invariant. Interestingly, the findings are consistent with unitary models of memory which consist of delay-invariant storage and retrieval processes (Jonides et al., 2008; Nairne, 2002). In other words, both LTM and STM are affected by this type of distortion.

The aim of this experiment is to investigate the mechanisms of false memory formation within STM in a study that replicates and extends those by Flegal et al. (2010) and Macé and Caza (2011). On the one hand, Flegal et al. highlighted that there was no difference between false memories in both STM and LTM tasks, however they did not take into account the processing differences across these two memory stores (e.g. articulatory suppression to impede rehearsal of the material). In particular, rehearsal is an important factor for the creation and maintenance of STM (Atkinson & Schiffrin, 1968) and this was not explored in their study using mathematical verification, which does not requires rehearsal. In contrast, we asked participants to remember a pair of numbers as a concurrent memory task, where the digits had to be sub-vocally rehearsed to be maintained together with the words of the list (Baddeley et al., 1984; Atkins et al., 2011). On the other hand, Macé and Caza did use auditory presentation and took into account articulatory suppression, yet they used 'mixed' lists of words (i.e. where words where associated to a common or not). Additionally, they were using lists of six words, which are toward the high-end of the STM span of 7 ± 2 (Miller, 1956). Therefore, long lists may have triggered memory processes beyond STM. Additionally, we investigated the role of the visual appearance of the stimuli by changing their font across presentation and testing. An effect of this manipulation would suggest that words underwent a very superficial processing based on visual appearance rather than 'deeper' semantic processing (Craik & Lockhart, 1972; Craik & Tulving, 1975).

In sum, here we employed a visual presentation of 'purely' themed 4-word lists, investigated the role of articulatory suppression (Baddeley & Hitch, 1974; Baddeley & Lewis, 1981), and of the visual appearance of the probes (i.e. font). We predict that probes semantically related to the list will be falsely recognised at a higher rate than those unrelated (Deese, 1959; Roediger & McDermott, 1995; Brainerd et al., 1995; Gallo & Roediger, 2002). Moreover, we predict that articulatory suppression would lead to an increase in the false recognition of related probes and decrease in the correct recognition of target probes.

To infer the level of stimulus processing, throughout the experiment the font of the probes was either maintained lowercase as within the list, or changed to uppercase. Prior studies on semantic memory have changed the font of the probe to infer the level of processing (i.e. visually and superficial, or semantically and deep), however such a manipulation has not been tested in the domain of false short-term memory (J.H. Coane, personal communication). Thus, in case of superficial processing, a font change from the lowercase of list to the uppercase of the probe would, for example, trigger more rejections of the related lures. In case of deeper processing (Craik & Tulving, 1975; Rhodes & Castel, 2008) we should not find such effect.

We also included the remember-know rating (Tulving, 1985) to investigate participants' phenomenological experience associated to the generation of false memories. In particular we want to determine whether false memories are more associated to a conscious 'remembering' of seeing the probe among the words of the list, or whether it is more connected to a vague 'knowing' that it was there –that is, without a conscious memory, but with a 'feeling' (see Slotnick & Schacter, 2004).

2. Method

Participants

We tested 66 undergraduate students (21 were males) of the Queen Mary University of London. Their age ranged from 19 to 22. Participants signed the consent form that was approved by the local Ethics Committee, thus complying with the Declaration of Helsinki on research ethics.

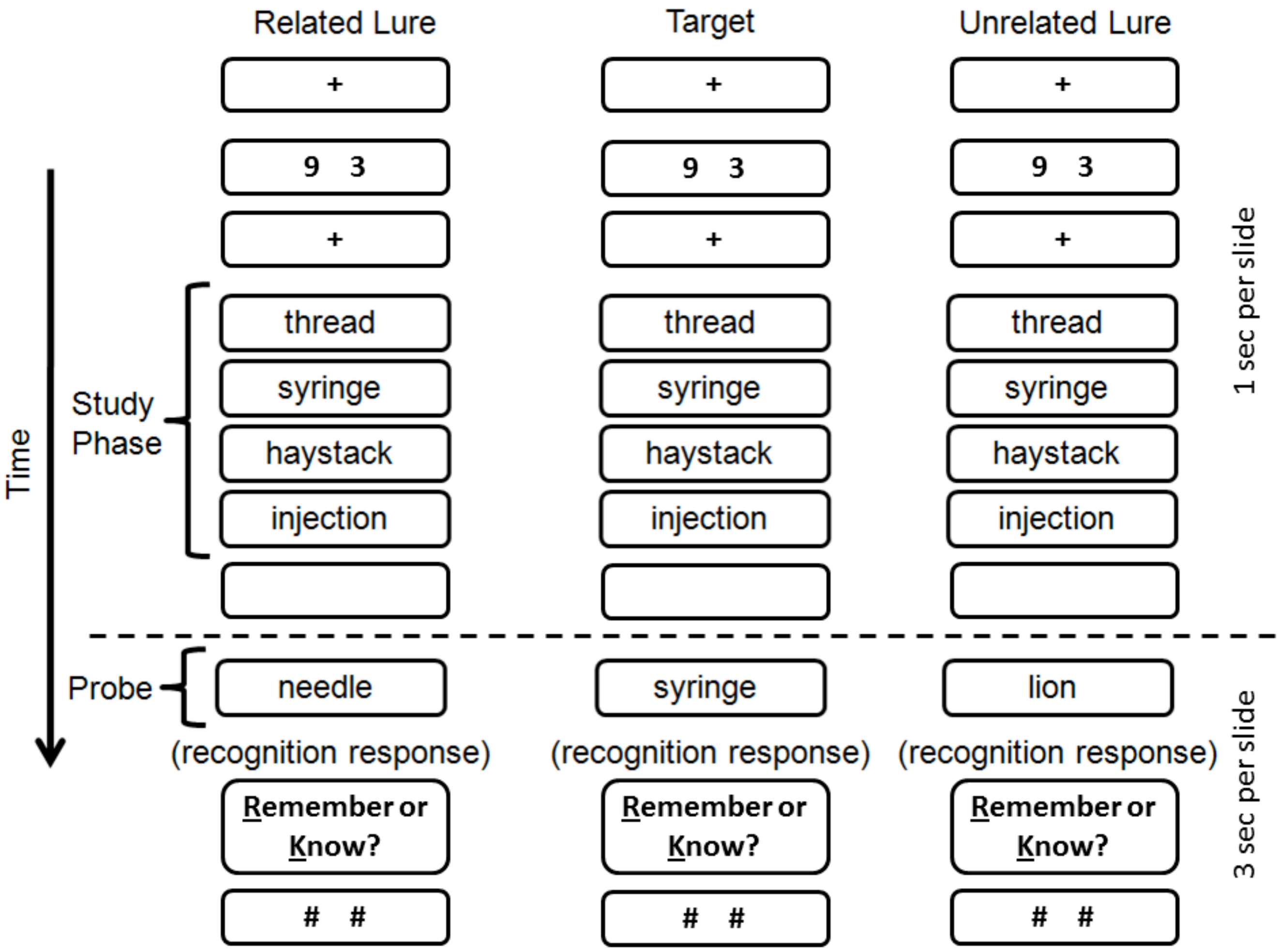
Procedure

Each participant was provided with a blank booklet containing seven pages. The first page was used for the age, sex, and answers to the two practice trials. Pages 2-6 contained the space for answering the 96 trials. The final page contained questions about their overall impression of the experiment. Participants were all seated in a lecture-theatre where they viewed the screens on which the words were presented.

Each trial containing four semantically related words. Each list was followed by a Related, a Target, or an Unrelated probe (32 probes for each of the three types; see Figure 1). Lists were extracted from Flegal et al. (2010). The stimuli were presented in PowerPoint using the timing controls within the program to control stimulus duration.

In Block 1, in each trial participants were presented with a pair of numbers that they had to sub-vocally rehearse and then recall at the end of each trial. Then it followed the list of four words where each word was presented for one second on the screens. After a one-second pause, a probe word was presented for three seconds. Participants wrote down whether the probe word was 'Old' (i.e. present in the list) or 'New'. The font of the probe was either Lowercase (as for the words of the list) or Uppercase. After the probe was presented, participants were prompted for three seconds to write whether they 'Remembered' the probe being showed on the screen (i.e. they could consciously remember it as displayed on the screen) or whether they more simply 'Knew' that it had been shown. The remembered-known statement was required only when the probe was considered Old. Finally, the '# #' on the screen prompted participants to write down the two numbers presented at the beginning of the

Figure 1: The depiction of a trial in Block 1



Notes: Related Probes were words that had not been presented in the preceding list but that were semantically related to them, Target Probes were words that had been presented in preceding list, and Unrelated Probes were words that had not been presented in the preceding list and that were unrelated to them. In Block 2 there was not neither the presentation of the pair of digits (i.e. "9 3") nor their test (i.e. "# #").

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trial (see Figure 1).

After the completion of Block 1, participants had a longer break before performing Block 2. Here participants were not presented with digits to rehearse; all the remaining details were the same is in Block 1, except that new lists were showed. The entire experiment took about 1 hour.

3. Results

For each participant we calculated the average number of errors across the twelve conditions (e.g. if the probe was judged as 'New' when it was actually 'Old' this was recorded as an error). Mean errors across participants are reported in Table 1. As a control for number rehearsal, we discarded the trials where participants could not remember the two rehearsed numbers. This was quite rare and involved less than 1% of the total number of trials. Our statistical approach involved an analysis of variance with the main factors covering the experimental design (e.g. type of rehearsal, type of probe, etc.); additionally interactions among main factors were further investigated by using Bonferroni-corrected post-hoc analyses.

We performed a 2x3x2 within-subjects ANOVA on the average error rates with Block (articulatory suppression, or rehearsal), Probe Type (Related, Target, or Unrelated) and Case (Uppercase or Lowercase) as variables. We found a significant effect of the Block [$F(1,64)=28.09$, $p<.01$] where rehearsed lists were better performed (0.19 average error) than when there was articulatory suppression (0.47 average error). Probe Type was significant too [$F(2,63)=41.46$, $p<.01$] with Unrelated probes generating least errors (0.04 average error), Target probes being in between (0.34 average error), and Related probes generating most errors (0.61 average error). The Case was not significant [$F(1,64)=1.76$, $p>.05$]. Finally we found a significant interactions between Block and Probe Type [$F(4,61)=13.21$, $p<.01$], and across Block, Probe Type, and Case [$F(6,60)=5.47$, $p<.05$]. No other interaction reached the significant level.

We corrected for the multiple comparisons by using the Bonferroni post-hoc analysis (see Figure 2). Block by Probe Type revealed that Related probes and articulatory suppression produced more errors than any other condition (0.90 average error), that Target probes with articulatory suppression produced the second biggest error rates (0.5 average error), while Unrelated probes

The results for Block 1 and 2

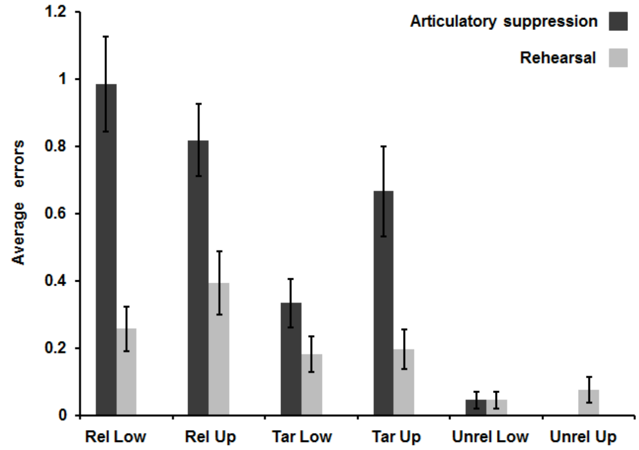
		Block 1		Block 2	
		Lower Case	Upper Case	Lower Case	Upper Case
Related	Mean	0.98	0.82	0.26	0.39
	(SD)	(1.16)	(0.88)	(0.53)	(0.76)
Target	Mean	0.33	0.67	0.18	0.20
	(SD)	(0.59)	(1.09)	(0.43)	(0.47)
Unrelated	Mean	0.05	0	0.05	0.08
	(SD)	(0.21)	(0)	(0.21)	(0.32)

Notes: Mean and standard deviations error rates associated to the Block 1 (articulatory suppression) and Block 2 (rehearsal) across the three types of probes (Related, Target, and Unrelated) and the two type of case (Lowercase and Uppercase).

in both Block 1 and 2 where the best performed (0.02 and 0.06 average error respectively) [all p<.05]. In sum, post-hoc contrasts confirmed that articulatory suppression and Related probes produced more errors –namely, false memories. Finally, the interaction Block by Probe Type by Case confirmed that Related probes both Uppercase and Lowercase in Block 1, together with the Target Uppercase probes in Block 1 were those generating more errors [all p<.05] (see Figure 2).

We further analysed the phenomenological experience relative to the creation of false memories, thus focusing on the errors produced by the participants. Therefore, for the trials that *did* generate false memories across the Related and Unrelated conditions (i.e. when a New probe was judged as Old) we calculated how many times these erroneously chosen probes were experienced as Remembered and how many were experienced as Known. In other words we tried to determine the conscious experience associated to trials generating false memories. On these means it was performed a 2x2x2x2 within-subjects ANOVA with Attribution (Remembered or Known), Block (articulatory suppression, or rehearsal), Probe Type (Related or Unrelated), and Case (Uppercase or Lowercase) as variables. Attribution was not significant [F(1,64)=1.62, p>.05]. Block was significant [F(1,64)=21.49, p<.01] indicating that articulatory suppression produced more Remember-Know judgements (i.e. errors) (2.79 on average) than when rehearsal was allowed (1.07 on average). Ultimately, this confirms that articulatory suppression produced more false memories (errors) than when rehearsal was allowed. We found a significant effect of the Probe Type [F(1,64)=89.23, p<.01], where Related probes triggered higher Remember-Know ratings (3.72 on average) than Unrelated probes (0.14 on average), thus confirming that Related probes produced more false memories. The case was not significant [F(1,64)<1]. The interaction Attribution by Probe Type was marginally significant [F(3,62)=2.79, p=.10]. We investigated this interaction with the Bonferroni post-hoc analysis and found that Related probes (i.e. those generating most of the false memories) were more often judged as 'known' rather than 'remembered' [p<.05]. Finally, the interaction Block by Probe Type was significant [F(3,62)=32.73, p<.01], that further confirmed that articulatory suppression and Related probes generated more Remember-Know judgements and thus more false memories. No other interaction was significant.

Figure 2: Recognition task results



Notes: Average errors associated to the recognition task where 'Articulatory suppression' indicates Block 1 and 'Rehearsal' Block 2. Additionally, 'Rel' stands for Related probes, 'Tar' for Target probes, 'Unrel' for Unrelated probes, 'Low' for Lowercase, and 'Up' for Uppercase. Error bars represent the ± SE.

4. Discussion

In the present study we investigated the factors influencing the generation of false memories in STM. We found that the main factors were: the Probe Type and the possibility to use sub-vocal rehearsal. Related probes generated more false memories than Unrelated probes. This is consistent with previous studies such as that by Atkins and Reuter-Lorenz (2008), Flegal et al. (2010), and Coane et al. (2007) who all observed a strong effect of Related lures in STM memory tasks. This suggests that semantic processing does occur at the STM level, thus that deep semantic processing occurs rapidly after stimulus presentation. These results expand the scope of theories such as the fuzzy trace theory (Brainerd et al., 1995) and the activation monitoring theory (Gallo & Roediger, 2002). The fuzzy trace theory hypothesises that the memory traces of the lists are actually fuzzy, and false memories are generated by the semantic relation shared by probes and the fuzzy traces of the list (Arndt, 2011). The activation monitoring theory (Gallo & Roediger, 2002) proposes that the presentation of a probe causes an activation which spreads to the 'neighbouring' items stored within semantic memory (Collins & Loftus, 1975; Quillian, 1967). The spread of activation is monitored by processes which determine its 'authenticity' (i.e. that is, which distinguish between 'real' activation and the mere spread of activation from neighbours). False memories occur when a probe triggers a level of activation sufficient to bypass the monitoring processes (Gallo, 2006). Therefore, our results suggest that the same theories on false memories formation in LTM are valid for STM as well. In particular, considering the activation monitoring theory, the monitory process can be represented by the central executive component of the STM/working memory (Baddeley, 1986).

Additionally, another main result was the crucial role played by rehearsal in the accuracy of STM (see Macé & Caza, 2011). Thus, when participants were prevented from sub-vocally rehearsing the words of the list, this had an overall negative impact on STM performance.

Baddeley's working memory model (Baddeley, 1986) uses rehearsal to consolidate memory traces, thus articulatory suppression results in the failure of proper memory formation. Therefore, our results can be explained by the general cost produced by articulatory suppression, which can be even more deleterious when coupled with probes Related to the words of the list.

There was a weak effect of the font manipulation, suggesting that words underwent deep semantic processing (Craik & Tulving, 1975). The sole significant effect was to render more difficult the recognition of Target probes (i.e. words that were actually on the list) when sub-vocal rehearsal was suppressed (see Figure 2). In this case, participants relied more on the visual features of the words to encode them in STM. Aside this effect, the significant level of false memories for Related probes implies that participants mainly encoded the words non-visually. This processing rapidity is supported by behavioural data on both semantic and non-semantic material (Kovács, 1996; Longtin &Meunier, 2005; Marr & Marr, 1976) and electrophysiological evidence (Penolazzi et al., 2007; Hinojosa et al., 2004).

The phenomenological experience more associated to false memories formation was of vaguely Knowing, rather than Remembering, that the probe was in the list. This is different from previous results (e.g. Flegal et al., 2010), reporting that false memories are more associated to consciously Remembering a Related probe being in the list. This difference perhaps arises from the more extensive manipulations to the stimuli: here participants had to deal with articulatory suppression, remembering antagonist material (pair of numbers), and changes in typeface in addition to the remembering the list of words and rejecting incorrect probes. This may have triggered a higher cognitive effort, resulting in the feeling that that the task was quite demanding and thus making participants less assertive in their judgements – thus, preference for Knowing over Remembering. In fact, in support of this line of reasoning, Knowing was chosen more in the more demanding conditions (i.e. Related probes and articulatory suppression).

In sum, the present study provides further evidence that the creation of false memories can occur in STM (Coane et al., 2007; Flegal et al., 2010) by showing that semantic processing is already taking place and that visual cues associated to the stimuli are irrelevant, thus supporting the hypothesis that semantic processing occurs early. Future studies should address if such early 'high level' processing is performed at the level of primary sensory cortices, which are thought to be involved only in basic perceptive aspects. This may not be too surprising as the attribute of the sensory specificity (e.g. primary visual cortex specific for visual input) seems to fade (Ghazanfar & Schroeder, 2006; Pasqualotto & Proulx, 2012).

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Legends

Figure 1: The depiction of a trial in Block 1. Related Probes were words that had not been presented in the preceding list but that were semantically related to them, Target Probes were words that had been presented in preceding list, and Unrelated Probes were words that had not been presented in the preceding list and that were unrelated to them. In Block 2 there was not neither the presentation of the pair of digits (i.e. “9 3”) nor their test (i.e. “# #”).

Figure 2: Average errors associated to the recognition task where ‘Articulatory suppression’ indicates Block 1 and ‘Rehearsal’ Block 2. Additionally, ‘Rel’ stands for Related probes, ‘Tar’ for Target probes, ‘Unrel’ for Unrelated probes, ‘Low’ for Lowercase, and ‘Up’ for Uppercase. Error bars represent the ± SE.

Table 1: Mean and standard deviations error rates associated to the Block 1 (articulatory suppression) and Block 2 (rehearsal) across the three types of probes (Related, Target, and Unrelated) and the two type of case (Lowercase and Uppercase).

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