

Open University of Cyprus

Faculty of Pure and Applied Sciences

Postgraduate (Master's) Programme of Study *Cognitive
Systems*

Postgraduate (Master's) Dissertation



The Effects of Long-Term Representations on Attentional
Orienting in Visual Short-Term Memory

Ioannis Karapanagiotidis

Supervisor
Andria Shimi

May 2020

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fulfilment of the requirements for the postgraduate degree

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Summary

How long-term representations influence attentional orienting within visual short-term memory (VSTM)? Inspired by previous findings suggesting that familiar items generate multiple codes that activate both visual and semantic traces in long-term memory (LTM), we associated via training, unfamiliar abstract shapes with familiar items to examine the impact of these newly-formed LTM representations on VSTM performance. Furthermore, we manipulated the type of mental associations created between familiar and unfamiliar items to include mental associations of the abstract shapes with a) either visual familiar items (images of known animals) or b) auditory familiar items (the sounds of the name of these animals), in order to investigate the effects of the presentation modality on the strength of the mental associations.

Young adults, who were assigned in one of two experimental groups (one per presentation modality) and were first asked to complete the learning/association task, were compared with a "no learning" control group, in an attentional orienting task (AOT). In AOT, participants had to decide whether a probe item was a member of a previously presented memory array, consisted of four different images (familiar animals or unfamiliar abstract shapes). Critically, we used visuospatial attentional cues during the maintenance period to orient participants' attention to specific locations within the arrays held in VSTM.

Results indicated three key findings. First, all participants were more accurate with familiar items compare with unfamiliar items. Second, all participants were more accurate and faster when the attentional cues were spatially informative, and this was the case for both familiar and unfamiliar items. Last and more importantly, there was an effect of learning on participants' accuracy, suggesting the existence of a training effect. Taken together these findings, contribute to a growing body of knowledge that highlights the interaction between familiarity of information and attentional orienting in VSTM.

Περίληψη

Πώς επηρεάζουν οι αναπαραστάσεις της μακρόχρονης μνήμης τον τρόπο που προσανατολίζουμε την προσοχή μας εντός της οπτικής βραχύχρονης μνήμης (OBM); Εμπνεόμενοι από προηγούμενα ευρήματα, που προτείνουν ότι τα οικεία αντικείμενα δημιουργούν πολλαπλού τύπου κωδικοποίηση, η οποία ενεργοποιεί τόσο οπτικά όσο και σημασιολογικά ίχνη στη μακρόχρονη μνήμη, συσχέτισαμε μέσω εκπαίδευσης άγνωστα αφηρημένα σχήματα με οικεία αντικείμενα, για να εξετάσουμε τον αντίκτυπο αυτών των πρόσφατα σχηματισμένων αναπαραστάσεων στην απόδοση της OBM. Επιπλέον, χειριστήκαμε πειραματικά τον τρόπο της εκπαίδευσης, ώστε να περιλαμβάνει τις νοητικές συσχετίσεις των αφηρημένων σχημάτων είτε α) με οπτικά οικεία αντικείμενα (εικόνες γνωστών ζώων), είτε β) με ακουστικά οικεία αντικείμενα (τον ήχο του ονόματος αυτών των ζώων), προκειμένου να εξετάσουμε τυχόν επιδράσεις του τρόπου παρουσίασης στη δύναμη των διανοητικών συσχετίσεων.

Νεαροί ενήλικες κατανεμήθηκαν σε τρεις διαφορετικές ομάδες: δύο πειραματικές (μία ανά τρόπο παρουσίασης) που πραγματοποίησαν την εκπαίδευση / συσχέτιση και μία ομάδα ελέγχου που δεν έκανε εκπαίδευση. Αργότερα, όλες οι ομάδες πραγματοποίησαν ένα έργο προσανατολισμού προσοχής (ΕΠΠ). Στο ΕΠΠ οι συμμετέχοντες έπρεπε να αποφασίσουν την παρουσία ή όχι ενός προς ανίχνευση αντικειμένου σε έναν πίνακα μνήμης που είχε παρουσιαστεί προηγουμένως και αποτελούνταν από τέσσερις διαφορετικές εικόνες (γνωστών ζώων ή άγνωστων αφηρημένων σχημάτων). Κατά τη διάρκεια της περιόδου διατήρησης, χρησιμοποιήσαμε οπτικοχωρικές ενδείξεις προσοχής, για να κατευθύνουμε την προσοχή των συμμετεχόντων σε συγκεκριμένες τοποθεσίες μέσα στη μνημονική αναπαράσταση του πίνακα που διατηρούσαν στην OBM.

Οι αναλύσεις των δεδομένων κατέληξαν σε τρία βασικά ευρήματα. Πρώτον, όλοι οι συμμετέχοντες ήταν πιο ακριβείς στα οικεία αντικείμενα σε σύγκριση με τα άγνωστα αφηρημένα σχήματα. Δεύτερον, όλοι οι συμμετέχοντες ήταν πιο ακριβείς και ταχύτεροι, όταν οι οπτικοχωρικές ενδείξεις προσοχής ήταν χωρικά ενημερωτικές, πράγμα που συνέβαινε τόσο για τα οικεία όσο και για τα άγνωστα αντικείμενα. Τέλος, υπήρξε επίδραση της μάθησης στην ακρίβεια των συμμετεχόντων, γεγονός που υποδηλώνει την ύπαρξη εκπαιδευτικού αποτελέσματος. Συνολικά, τα ευρήματα συμβάλλουν στην βιβλιογραφία που τονίζει την αλληλεπίδραση μεταξύ της οικειότητας των πληροφοριών και του προσανατολισμού της προσοχής στην OBM.

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Chapter 1

Introduction

Visual short-term memory (hereafter 'VSTM') is a memory system that provides temporary visual information storage, while simultaneously, maintaining this information in a readily accessible state to address the needs of the tasks at hand. Interestingly, VSTM holds a core position in humans' cognitive ability due to its involvement in a wide array of mental processes, including the control of saccadic eye movements (Hollingworth et al., 2008), the allocation of attention (Awh & Jonides, 2001), and general fluid intelligence (Fukuda et al., 2010). A defining feature of VSTM is its limited capacity (Luck & Vogel, 1997). Therefore, taking into consideration the pivotal role it plays in cognition, it is not strange that it has long captivated intense research efforts to provide quantitative estimates of this limitation, e.g., the magical number 4 for simultaneously presented elements (Cowan, 2001). Given that we can hold as mental representations a minute fraction of the visual world, it is vital to select only the task-relevant information for encoding and maintenance (Chun et al., 2011); but which cognitive processes affect this selection?

A valuable approach to gain informative insights into this selection procedure is the examination of the intimate relation between VSTM and selective attention (Griffin & Nobre, 2003; Kiyonaga & Egnér, 2013). Ample evidence indicates a positive correlation between attention efficiency and memory of the to-be-remembered stimuli (Awh et al., 2006; Awh & Jonides, 2001; Chun et al., 2011; Gazzaley & Nobre, 2012; Kuo et al., 2012), suggesting that the more refined our selective attention is, the better our VSTM performance is. Driven by this knowledge, a recent line of research proposes that instead of approaching these two cognitive functions in isolation, it is beneficial to experimentally investigate memory processes by taking into account the contribution of attentional mechanisms (Shimi & Scerif, 2017), which may mediate the efficiency of memory performance. Thus, research methodologies that acknowledge the liaison between VSTM and selective attention can shed light on how these cognitive constructs interact and affect selection processes.

Indeed, convergent findings from different studies highlight the importance of top-down attentional mechanisms in mnemonic functions. For example, Griffin and Nobre (2003) demonstrated that it is possible to orient spatial attention to internal representation in a similar manner to orienting to perceptual stimuli. Notably, they showed that the presentation of attention-directing cues during the maintenance period enhances VSTM performance. Other studies propose that attentional orienting can protect the maintenance of particular items from decay or proactive interference (Makovski et al., 2008; Matsukura et al., 2007). Relevant evidence in the literature shows that spatial attentional orienting influences search processes and optimizes retrieval from VSTM (Nobre et al., 2007). Likewise, Lepsien and Nobre (2006) suggested that attentional orienting affects the retention of relevant items in VSTM by enhancing their active maintenance and/or suppressing the activation of unnecessary items. As a whole, this growing research body demonstrates that the employment of top-down attentional control facilitates encoding and retention of visuospatial information in adults' VSTM.

A suitable methodological approach to examine the role of attentional orienting in VSTM performance is the cueing partial-report paradigm, initially coined by George Sperling in his influential work about iconic memory (Sperling, 1960) and later extended to VSTM. In this paradigm, visuospatial cues are presented before (pre-cues) or after (retro-cues) the to-be-remembered array of items. The function of the cues is to guide attention to one element in the array and participants have to decide if a subsequent probe item was a member of the previously presented array. Importantly, because it is a task that involves both transfer of information to VSTM and shifts of attention, it constitutes a well-established attentional orienting task that can detect the interaction of top-down attentional biases with VSTM's inner workings (Shimi & Scerif, 2017). This discriminative ability is evident in a wealth of studies that adopted this paradigm and indicated the significance of visuospatial attention, as a determinant, in the selection of the to be encoded and maintained information in VSTM (Lepsien et al., 2011; Makovski et al., 2008; Matsukura et al., 2014; Matsukura & Hollingworth, 2011).

A factor that acts synergistically with top-down spatial biases and impacts VSTM performance is the nature of memoranda. To understand further the precise effects of differential memoranda on adults' spatial attentional biases during maintenance, Shimi and Scerif (2015) manipulated the nature of the memoranda in the cueing partial-report

paradigm to depict either highly familiar (i.e., animals) or unfamiliar items (difficult to label, abstract shapes). Their findings showed that the type of the to-be-remembered information interacts with attentional control and influences how well we maintain representations in VSTM. More specifically, the authors reported robust effects of the type of the memoranda on selective attention and VSTM, with spatial attentional biases during maintenance facilitating the later recognition of familiar items. This finding combined with the importance of non-refreshable features (Ricker & Cowan, 2010), i.e., visual characteristics that cannot be refreshed by attention and are gradually lost with time, demonstrates that the nature of the memoranda affects our ability to refresh the material we maintain in our VSTM, and thus the selection of the relevant information (Shimi & Scerif, 2015, 2017).

Critically, Shimi and Scerif (2015, 2017) propose that the more efficient retrieval of the familiar, compared with unfamiliar, items suggests that we retain, whenever possible, internal representations with multiple codes. Meaning that, when we are presented with familiar information to-be-remembered, besides the visual code, we also generate a semantic code that comprises the meaning we attribute to the items, in line with the dual coding theory (Paivio, 1971). According to this theory, we employ both verbal and nonverbal encoding to form internal representations for visually-presented items; i.e., we create both visual and semantic memory traces for a visual stimulus. Based on this theoretical framework, it seems plausible that familiarity activates prior semantic knowledge in long-term memory (LTM) and consequently benefits attentional orienting, in function of VSTM, and ultimately recognition (Shimi & Scerif, 2017).

The proposal about the existence of multiple mental codes produced by different types of memoranda has the potential to provide a complementary framework (Cowan & Alloway, 2009) to the capacity limit approach regarding performance differences in VSTM. There is a growing appreciation for the notion that we generate both visual and language-based memory traces that lead to an additive benefit in recall. For example, Postle and colleagues propose that the mnemonic representation of visually presented object stimuli may encode not only the visual features of the object (e.g., size, color), but also verbal information (possibly semantic), associated by the individual with the visual stimulus (Postle et al., 2005). Likewise, the episodic buffer, the last added module of the multicomponent model of working memory (WM), is responsible for representing and

integrating information from all subcomponents of WM and LTM in a multidimensional code (Baddeley, 2000).

1.1 Hypotheses

Given the above findings, which emphasize the significance of attention control and familiarity factors for the maintenance of information in VSTM, it seems important to understand better the role of long-term representations on selective attention and VSTM. It has been previously proposed that the efficiency with which we maintain information in VSTM does not solely depend on attentional control, but it also relies on the potential existence of multiple codes that provide an additional semantic trace in LTM (Shimi & Scerif, 2015, 2017). Thus, the additive benefit of having multiple codes (visual and semantic) facilitates refreshing of the memoranda in our VSTM and hence increases the likelihood of successful recognition. However, such a proposal remained to be examined with newly created long-term representations for items that were previously unfamiliar but later became familiar.

To bridge this gap in the literature, we associated via training, unfamiliar shapes with prior knowledge, and examined the magnitude of attentional biases on the maintenance of these newly-formed LTM representations over the maintenance of unfamiliar items that were not associated with prior knowledge. Specifically, participants associated unfamiliar abstract shapes with familiar items (a known animal). Importantly, this manipulation has the power to induce multiple mental codes (visual and semantic) for previously unfamiliar abstract shapes and to trigger their access in LTM, resulting thus in more strengthened mental representations, similar to how the familiar items in the study by Shimi and Scerif (2015) functioned.

We hypothesized that participants would benefit more from attentional cues and demonstrate better VSTM performance in a condition where the unfamiliar objects have been associated with familiar items (and thus generated multiple codes) compared with a condition where unfamiliar items generated only one mental code. In particular, we examined two measures of VSTM performance, accuracy and reaction time, expecting from participants who completed the association training to respond more accurately and faster in an attentional orienting task compared with a control group. Of note, the

encoding and maintenance of unfamiliar items used in the dissertation rely on an outline of their arbitrary shape, which prevented the labeling of these items during their short presentation. This feature suggests that initially these abstract items have no meaning and hence participants do not rely on any existing knowledge for their encoding.

This dissertation also investigated possible differential effects of the presentation modality on the strength of newly created mental associations and selective attention. More specifically, we manipulated the association of the visual abstract item with a) another visual familiar item (the image of an animal) or b) an auditory item (i.e., the sound of the name of an animal). This experimental manipulation aimed to elucidate further, whether long-term representations are easier to be generated for one presentation modality over others and if so, whether this impacts the magnitude of attentional cueing effects on VSTM performance.

The manipulation of the presentation modality can extend our knowledge about the nature of the codes with which information is represented in VSTM when it is received through different sensory modalities (visual and auditory). The generally accepted dual coding theory (Paivio, 1971) suggests that mental representations maintain some concrete qualities of the external stimuli from which they originate, meaning that depending on the input sensory modality, they retain different types of mental codes. Based on this theoretical framework, the newly-created mental representations from the association of a visual abstract item with a visual familiar item entails the generation of a visual and a semantic code (Shimi & Scerif, 2015). In contrast, the association of a visual abstract item with an auditory item hypothetically entails the generation of a visual and a phonological code. Therefore, it is important to examine the effects of the nature of multiple codes on the strength of the newly created long-term representations and on the magnitude of attentional biases during maintenance in VSTM.

In summary, this dissertation posed the following research questions: first, do long-term representations of highly familiar items influence the maintenance of information in VSTM? Second, to what degree the modality of presented information facilitates learning and, consequently, the maintenance of information in VSTM?

Chapter 2

Method

2.1 Participants

Thirty-three adults (9 males and 24 females) between 18 and 38 years old ($M = 21.70$ years old, $SD = 3.56$) were recruited through the Memory and Attention Development Lab's online research participation system (SONA). All of them were undergraduate students who participated in return for course credit.

2.2 Apparatus

Three types of tasks were used to investigate our hypotheses. In particular, two variations of a learning task, one for each presentation modality (visual-visual, visual-auditory) and an attentional orienting task.

2.2.1 Visual Learning Task

The visual learning task included three phases. In the first phase participants were instructed to learn pairs of images. On every trial, participants saw two images presented together, i.e., an unfamiliar abstract shape and a familiar animal (see Figure 1A). Participants were instructed to associate the two images together. There were 8 pairs of images, each pair presented on 3 consecutive trials. Subsequently, on the fourth trial, participants were presented with the image of the animal along with the eight candidate abstract shapes and were asked to choose the shape that was previously associated with the animal (see Figure 1B). This phase was accumulative, meaning that after every four trials, a new pair of shape-animal was introduced to participants until the presentation (and therefore association) of all eight pairs. The second phase was, in essence, a validation of the learning that took place in the first phase of the task, implemented as a test. During this phase, participants viewed consecutively an animal image along with all 8 abstract shapes (see Figure 1B) and had to pair the animal with the correct shape. This was done until participants identified all eight pairs correctly. The third and final phase

of the visual learning task was similar to the second phase except that participants viewed an abstract shape along with all 8 candidate animals and they had to select the one that represented the abstract shape (see Figure 1C). Again, participants' goal was to identify correctly all abstract shape-animal pairs.

The visual learning task included 132 learning trials, which were organized in three blocks of 44 learning trials (first phase of the learning task). In the second phase, that is, in the first validation test, participants had to achieve an 8 out of 8 score three times (3 x 8/8), i.e., they had to identify correctly all eight "known animal - abstract shape" pairs from the presented sets three times (see Figure 1B). If a participant failed to score 8/8, the validation process continued until the 8/8 score was accomplished. The third phase (second validation test), which asked participants to identify the animal's image that represented a given abstract shape (see Figure 1C), occurred 30 times for each pair. Critically, participants completed 30 test trials irrespective of their accuracy score (that is, even if they had perfect accuracy scores) to ensure that they learned the pairs well.

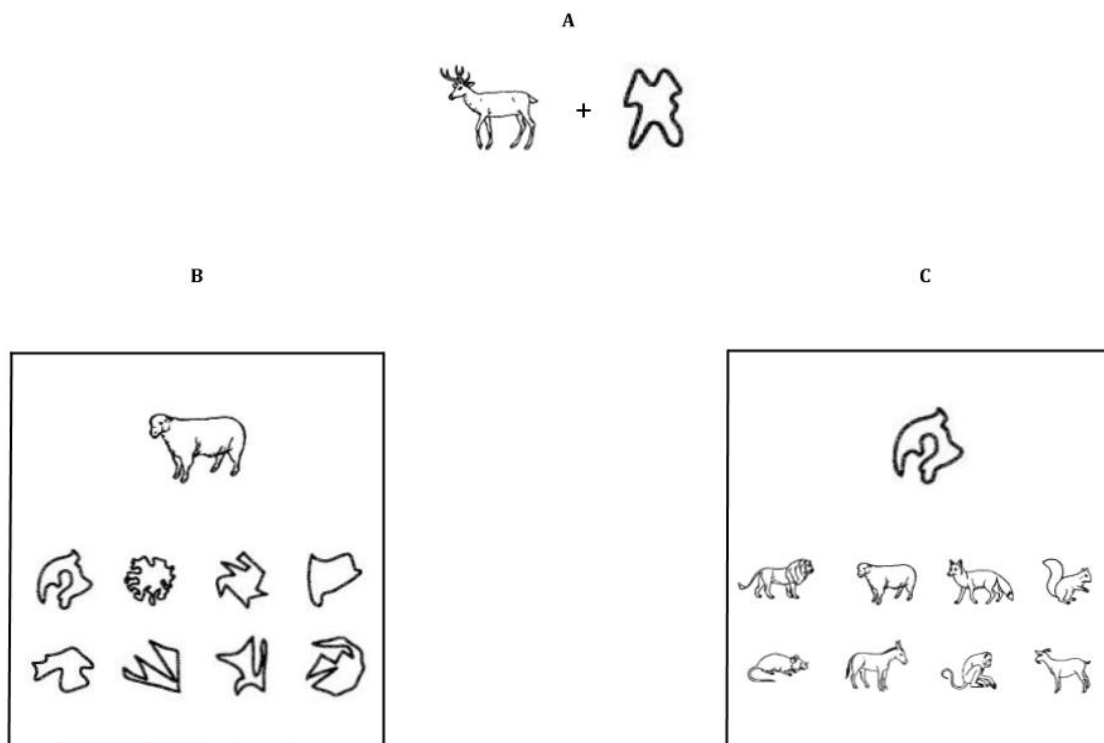


Figure 1. Schematic Illustration of the Visual Learning Task.

(A) First Phase: Association.

(B) Second Phase: Validation (1st Test).

(C) Third Phase: Validation (2nd Test).

2.2.2 Auditory Learning Task

The auditory learning task had an identical structure and number of trials with the visual learning task. However, it manipulated the presentation modality of the animals in three ways. First, during the first phase (learning), participants saw the image of an abstract shape simultaneously with the sound of the name of an animal (see Figure 2A), instead of seeing two images (an abstract shape and an animal) side-by-side. Second, during the first validation test, participants had to choose among eight abstract shapes alternatives the image that represented the name of the animal they heard in their headphones (see Figure 2B). Third, in the second validation phase, participants had to choose the animal that represented the abstract shape from an array of words (see Figure 2C), instead of images. Similarly to the visual learning task, participants had to score 3 x 8/8 on the first validation test, and complete 30 test trials regardless of their accuracy score in the second validation test.

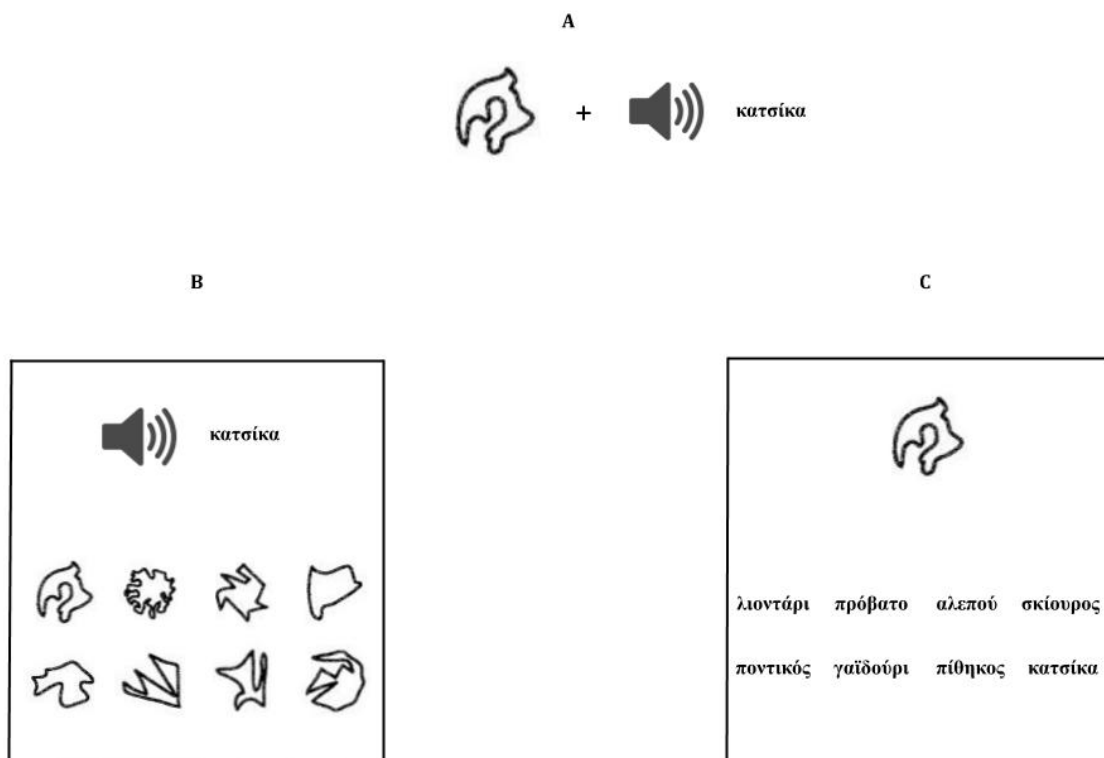


Figure 2. Schematic Illustration of the Auditory Learning Task.

(A) First Phase: Association.

(B) Second Phase: Validation (1st Test).

(C) Third Phase: Validation (2nd Test).

2.2.3 Attentional Orienting Task

The Attentional Orienting Task (AOT) was identical to the one used by Shimi and Scerif (2015). On every trial, participants saw a memory array with four different images (familiar animals or abstract shapes) arranged symmetrically at its four corners (see Figure 3A). Participants had to remember this array because it would be soon disappeared. After a variable time interval, an attentional orienting cue that was either spatially informative (retro-cue) or spatially uninformative (neutral) was shown to the participants. Its purpose was to provide information about the location of the to-be-probed image in the memory array. Following the cue, participants saw at the center of the screen a single image (an animal or a shape depending on the images presented in the memory array) and they had to decide whether the image was one of the four images previously presented in the memory array, by pressing the analogous mouse button (left for “YES” or right for “NO”). The three successive phases of the AOT with their detailed temporal parameters are schematically depicted in Figure 3A.

AOT was designed as an easy and fun memory game, in which participants had to help a pirate in a treasure hunting scenario. The game unfolded in four different islands that represented the test blocks of the AOT. Participants' goal at each island (test block) was to collect as many points as possible to help the pirate find the lost treasure. In total, AOT contained 192 experimental trials organized in four test blocks (islands) of 48 trials each. Of note, 67% of the trials (128) were probe present, and 33% (64) were probe absent (see Figure 3B). Two of the four blocks presented memory arrays of animal images, while the remaining two comprised memory arrays of abstract shapes. All blocks were counterbalanced across participants and their presentation order alternated throughout testing. Half of the total trials (96) contained retro-cues with an equal likelihood to point to one of the four quadrants of the memory array, while the other half were neutral. Notably, a black arrow illustrated the retro-cues and a black filled square the neutral cues (see Figure 3B) and retro-cue and neutral trials appeared randomly within each block.

2.2.4 Stimuli

Familiar items in the two learning tasks and AOT were black and white line drawings obtained from Snodgrass & Vanderwart (1980). In particular, for the visual and auditory learning tasks, we used the following animal images: donkey, monkey, fox, lion, sheep, squirrel, goat, and mouse. For the AOT we used the following images: bear, camel, horse,

kangaroo, pig, rabbit, frog, and turtle. In probe present trials of the AOT, the four images of the memory array were selected randomly and the probe image was one of the previously presented four images. In probe absent trials of the AOT, the probe was a fifth image drawn from the same list of the remaining eight images. The abstract shapes that constituted the unfamiliar items in the learning tasks and AOT were taken from Endo et al. (2003). The learning tasks (visual, auditory) and the AOT were presented with E-Prime 2.0 (Psychological Software Tools, Inc., Sharpsburg, PA).

All images were resized to 128 x 90 pixels and animal line drawings were further processed in Adobe Photoshop CC 2019 (version 19.0) to darken their outline so that it matched in darkness the outline of the abstract shapes. Also, the image of the sheep was further processed to remove one ear. During pilot, some participants mentioned that they confused the ears of the sheep with bull horns. For this reason, we removed the right ear from the original stimulus to avoid confusion and ensure that all participants correctly perceived the sheep as such (see Figure 4). The audio stimuli for the auditory learning task were recorded with an RØDE NTK condenser microphone and a TASCAM DR-05 digital recorder at 24bit / 96kHz quality. All recordings were denoised, normalized at 0 dB, and equalized in Audacity (version 2.3.3) to avoid distortions and booming during playback.

2.3 Procedure

Participants were tested in the Memory and Attention Development Lab (MADLab), at the University of Cyprus. When participants arrived in the lab, they were asked to read and sign the informed consent form. The research procedure was divided into two phases: 1) the learning phase, in which participants had to associate a series of abstract shapes with familiar animals via training (explained in the Visual/Auditory Learning Task), and 2) the test phase in which they had to perform the AOT. Participants, assigned in one of the two experimental groups (visual-visual or visual-auditory), carried out both phases, with a compulsory five-minute break in-between, during which they watched an animation video to standardize conditions during the break. Participants assigned to the control group completed only the AOT with no a priori learning.

The learning phase was self-explanatory. Both visual and auditory learning tasks began with four introductory slides that described the task in detail. Additionally, there were instructive slides before each validation phase (that is, before the validation tests), which provided all the necessary information for their completion. While participants read the initial on-screen instructions (the first 4 slides), the experimenter was present to answer any questions they may had about the learning task. Once participants reported that everything was clear, they began the learning task without the presence of the experimenter. Participants during the learning trials received immediate feedback regarding the accuracy of their answers. The feedback (“correct”, “incorrect”) was provided on-screen.

Prior to carrying out the AOT, the experimenter provided detailed information about the characteristics of the task. Both cueing conditions (retro-cue, neutral) and image types (animals, abstract shapes) were explained with examples on paper, as well as with actual on-screen practice trials (two blocks of six trials), each followed by feedback (“correct”, “incorrect”), to ensure that participants understood the task. Critically, participants were encouraged to perceive retro-cues as a form of assistance that could help them decide whether the probe was present in the memory array. During the AOT participants received feedback regarding the accuracy of their answers at the end of each block (islands in the memory game).

All participants sat at a fixed distance from the monitor (70 cm) and were instructed to focus their gaze on the fixation point. Participants responded with their right hand by clicking the left (YES) or right (NO) mouse button with their index and middle finger correspondingly. Participants were requested to respond as quickly as possible, but not randomly or without thinking about their answers first. The experimenter also informed participants that they could rest briefly when a break was offered during the AOT. Each experiment session lasted about 75 minutes for the two experimental groups and 30 minutes for the control group.

2.4 Statistical Design and Analyses

We analyzed the data using two different approaches: first, by carrying out analyses on datasets containing equal number of participants per experimental group and second, by carrying out analyses on the full dataset. For the first approach, we created three groups (2 experimental groups and one control group) with equal numbers of participants. The visual-visual group comprised 6 participants, the auditory-visual group comprised 5, and the control group comprised 6 participants. As a whole, the first dataset included data from 17 participants. For the second approach, we included the data collected from all 33 participants. More specifically, the visual-visual group comprised 22 participants, the auditory-visual group comprised 5 participants, and the control group comprised 6 participants.

In total, we conducted four separate repeated-measures analyses of variance (ANOVAs) on participants' accuracy scores (ACC) and median reaction times (RT), i.e., we conducted two ANOVAs (ACC and RT) for each dataset. Only trials with a correct response were included in the RT analyses. All ANOVAs had familiarity (familiar or unfamiliar stimuli), cueing type (retro-cue or neutral), and presence of the to-be-probed item (present or absent) as within-subjects variables. The learning modality with its three levels (visual-visual, visual-auditory, no learning) was the between-subject variable. Of note, the “no learning” condition was the control group, while the other two formed the experimental groups. Data were analysed with the SPSS software package (version 25).

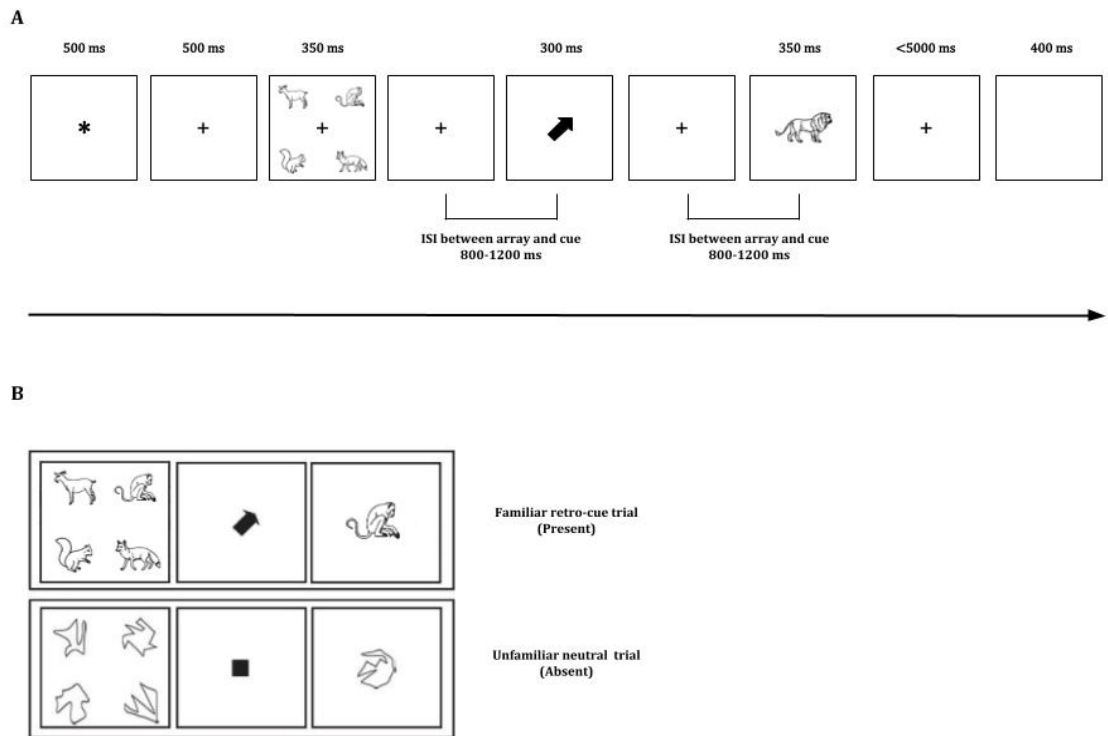


Figure 3.

(A) Schematic Illustration of the sequence of events and their temporal parameters in Attentional Orienting Task (AOT).

(B) Schematic Illustration of the AOT trial variations, in its familiarity (familiar vs. unfamiliar), cueing type (retro-cue vs. neutral), and presence (present vs. absent) conditions.

Chapter 3

Results

Results for equal numbers of participants (17 participants)

Accuracy

There were main effects of familiarity $F(1, 14) = 21.60, p < .001$, with participants being more accurate in familiar blocks ($M = .77$) compared to the unfamiliar blocks ($M = .70$), of cueing type $F(1, 14) = 23.68, p < .001$, where retro-cue trials ($M = .79$) yielded more accurate responses than the neutral trials ($M = .68$), and of presence $F(1, 14) = 7.51, p = .01$, which showed that participants were more accurate when the to-be-probed stimulus was absent ($M = .78$) than present ($M = .69$). The main effect of learning modality was also significant $F(2, 14) = 9.47, p = .002$, indicating as the more accurate condition the visual-visual group ($M = .80$), followed by the visual-auditory group ($M = .71$), and last with the smaller accuracy, the control group ($M = .69$). None of the interaction effects reached statistical significance.

Reaction Times

There were only main effects of cueing type $F(1, 14) = 82.49, p < .001$, driven by faster responses in retro-cue trials ($M = 549.46$) than in neutral trials ($M = 788.09$), and of presence $F(1, 14) = 69.84, p < .001$, caused by faster responses when the to-be-probed stimulus was present ($M = 603.12$) than absent ($M = 734.42$). The familiarity of the stimuli, the learning modality and all the interaction effects were non-significant.

Results for the full data set (33 participants)

Accuracy

Similarly to the 17 participants' dataset, there were main effects of familiarity $F(1, 30) = 21.69, p < .001$, with participants providing more accurate responses in the familiar blocks ($M = .75$) than in the unfamiliar blocks ($M = .68$), of cueing type $F(1, 30) = 48.66, p < .001$, with higher accuracy scores in the retro-cue trials ($M = .78$) than in the neutral trials ($M = .65$), and of presence $F(1, 30) = 6.02, p = .02$, which revealed that participants

were more accurate when the to-be-probed stimulus was absent ($M = .76$) than present ($M = .67$). There was no significant difference across the three experimental groups ($p = .11$). None of the other effects was statistically significant.

Reaction Times

There were main effects of cueing type $F(1, 30) = 133.86, p < .001$, caused by faster responses in retro-cue trials ($M = 564.99$) than in neutral trials ($M = 812.67$), and of presence $F(1, 30) = 78.81, p < .001$, driven by faster responses when the to-be-probed stimulus was present ($M = 625.01$) than absent ($M = 752.65$). Results indicated non-significant effects of familiarity ($p = .14$) and of learning modality ($p = .86$). Again, none of the interaction effects reached statistical significance.

Chapter 4

Discussion

It is now well established that visuospatial attentional control is of considerable importance for selecting what information will be encoded and maintained into VSTM (Griffin & Nobre, 2003; Kuo et al., 2012; Lepsien & Nobre, 2006; Makovski et al., 2008; Matsukura et al., 2014). Moreover, recent evidence demonstrates that the type of the to-be-remembered information interacts with spatial attentional biases and influences how well we maintain representations in VSTM (Shimi & Scerif, 2015). In this dissertation, we aimed to gain a better understanding of the role of long-term representations on attentional orienting in VSTM. By creating associations between unfamiliar items and prior knowledge via training, we explored the magnitude of attentional biases on the maintenance of these newly-formed LTM representations over the maintenance of unfamiliar items that were not associated with prior knowledge. We also manipulated the presentation modality of the training tasks to test if one modality (visual or auditory) generates more robust long-term representations than the other, and if so, whether this influences the magnitude of attentional cueing effects on VSTM performance differently in the two modalities.

Results provided robust evidence that directing attention with spatial informative cues during the maintenance period (retro-cues) enhances VSTM performance. The effect of cueing type on the accuracy and the reaction time with which participants retrieved information from VSTM was consistent across both datasets. All participants were more accurate and faster in retro-cue trials compared with neutral cue trials and this was the case for both familiar and unfamiliar items. This pattern of results is consistent with evidence from the retro-cue literature that demonstrates performance gains for informative visuospatial cues over neutral cues when orienting attention within mental representations of arrays (Astable et al., 2012; Kuo et al., 2012; Nobre et al., 2007).

Another finding of the dissertation was the effect of familiarity on participants' accuracy. Regardless of the dataset, participants recognized more accurately familiar stimuli

compared to unfamiliar items. This finding is in line with Shimi and Scerif (2015) work that manipulated the nature of the memoranda to depict either highly familiar (i.e., animals) or unfamiliar items (difficult to label, abstract shapes), and reported better maintenance for familiar items. Based on the above evidence, it has been proposed that we retain multiple codes for the internal representations of familiar items (Shimi & Scerif, 2015, 2017), meaning that familiarity besides the visual code, also generates a semantic code that activates prior knowledge in long-term memory (LTM), which consequently facilitates recognition. Our similar pattern of results replicates and provides further support to the multiple codes hypothesis regarding the internal representations of familiar memoranda.

Our results also revealed a main effect of the presence of the to-be-probed item on VSTM performance across both datasets. Specifically, all participants were slower when the probe item was absent from the memory array. It could be argued that when the to-be-probed stimulus appears, it triggers a search within the mental representation of the memory array. If it is an absent trial, then participants engage in a more exhaustive search in VSTM, which consequently increases reaction time. When it is a present trial, a direct comparison with one of the memory array items takes place (Shimi & Scerif, 2017), which can lead to a quicker match that avoids additional searches. This interpretation is compatible with the proposal that it is possible to locate an item within the internal representation of a memory array, in a similar manner to selecting perceptual stimuli (Kuo et al., 2009). Also, it is in line with the typical finding from the delayed match-to-sample task studies (e.g., Klaver et al., 1999), in which the probe absent stimuli generate slower responses.

Moreover, findings indicated that all participants were more accurate when the to-be-probed item was absent from the initial memory array. Based on the above results, which showed that participants were slower in absent trials, i.e., they were entangled in a prolonged search within VSTM, the cost in the response time most likely became a benefit for the accuracy of the answer. In other words, it seems plausible that the extra time participants spent to decide the absence of the probe item from the memory array, increased the accuracy of their responses.

By contrast, participants were less accurate when the to-be-probed stimulus was present in the memory array. Surprisingly, this pattern of results seems to suggest a speed-accuracy trade-off in the way participants responded in present and absent trials. Despite our interpretation of the high accuracy and slower response time in absent trials, it is not clear why participants responded faster but with lower accuracy in present trials.

The analyses of the data also showed an effect of learning on participants' accuracy. In descending order, starting from the most accurate group, findings indicated the visual-visual group as the one with the better performance, next the visual-auditory group, and last the control group. Based on the fact that the two experimental groups completed the learning phase before the AOT, it seems plausible that the learning procedure increased participants' acquaintance with unfamiliar stimuli, at such a level, that allowed them to be more accurate compared to the control group. This suggests that the learning trials produced to some extent long-term memory representations for the abstract items in the experimental groups, which increased the accuracy of their responses compared with the participants of the "no learning" condition who had no previous experience with the unfamiliar stimuli. Of note, the effect of learning was present only in the first dataset with the equal numbered groups. The absence of this finding from the full dataset may be explained by the unequal number of participants across the three groups. Specifically, 22 out of the 33 participants of the full dataset were members of the visual-visual condition. Thus, it may be that statistical analyses cannot detect a significant difference in learning with such a variation in set sizes.

Critically, the higher accuracy of participants in the learning groups is in line with the main hypothesis of interest, meaning that the association of the abstract shapes with prior knowledge, seemed to induce multiple mental codes that allowed LTM representations to improve VSTM performance. It is important to note that we were unable to investigate the relationship between familiarity and learning modality further, to clarify if the different training modality in the two experimental groups created stronger mental associations between familiar and unfamiliar items in one training group over the other and compared them with the control participants. The lack of an interaction effect between familiarity and learning modality did not allow to examine further the degree to which each group benefitted from the multiple codes that familiarity of an item may generate

In conclusion, results replicate previous findings (Shimi & Scerif, 2015) regarding the generation of multiple codes for the internal representations of familiar items that allow access in LTM representations, which in turn, produce more accurate responses for familiar stimuli. Unlike Shimi and Scerif (2015), we did not find a main effect of familiarity in the response time analyses, but only on participants' accuracy. This outcome may likely have occurred because of the small sample size of the control group in our study.

Furthermore, findings provide supporting evidence to the well-established benefit of retro-cues on VSTM performance (Astle et al., 2012; Griffin & Nobre, 2003; Kuo et al., 2012). All participants, regardless of the familiarity of the stimuli, performed better when attentional orienting during the maintenance period included spatial informative cues. In other words, participants of all groups were more accurate and faster in retro-cue trials than in neutral trials, for both familiar and unfamiliar items.

Interestingly, the overall better performance of the visual-visual group over the visual-auditory group may point to the association of two visual stimuli as the preferred presentation modality to produce a stronger learning effect. This finding can shed some light on our goal to examine which presentation modality can generate easier long-term representations. However, we were not able to investigate fully how each presentation modality impacts the magnitude of attentional cueing effects on VSTM performance. Unfortunately, the small sample size of participants in the visual-auditory group and the control group may be responsible for the lack of interaction effects in our results, which would have otherwise allowed us to gain a better understanding of how long-term representations generated by different modalities influence the maintenance of information in VSTM.

We are fully aware that the total number of participants (33) in our study cannot provide sufficient statistical power to detect significant effect sizes and interactions. Therefore, current results and interpretations should be treated with considerable caution. Nevertheless, despite this limitation, the present dissertation contributes to a growing body of evidence suggesting that the relations between visuospatial attentional control, VSTM, and LTM are interactive and that the nature of the memoranda influences the information we encode and retain in our memory.

Chapter 5

Conclusion

The main aim of this dissertation was to examine how long-term representations of highly familiar items influence the maintenance of information in VSTM, and to what degree the modality of the to-be-remembered information facilitates learning and, consequently, maintenance in VSTM. The results replicated that familiar memoranda generate multiple codes and provided robust evidence that retro-cues enhance VSTM performance. Moreover, they suggested that representations generated by associating two visual stimuli together may lead to better VSTM performance than representations generated by associating a visual stimulus with an auditory stimulus. Although future research is needed to confirm current results, this dissertation contributes further to our knowledge about the interaction between familiarity of information and attentional orienting in VSTM.

References

- Astle, D. E., Summerfield, J., Griffin, I., & Nobre, A. C [Anna Christina] (2012). Orienting attention to locations in mental representations. *Attention, Perception & Psychophysics*, 74(1), 146–162. <https://doi.org/10.3758/s13414-011-0218-3>
- Awh, E [E.], Vogel, E. K., & Oh, S.-H. (2006). Interactions between attention and working memory. *Neuroscience*, 139(1), 201–208. <https://doi.org/10.1016/j.neuroscience.2005.08.023>
- Awh, E [Edward], & Jonides, J. (2001). Overlapping mechanisms of attention and spatial working memory. *Trends in Cognitive Sciences*, 5(3), 119–126. [https://doi.org/10.1016/S1364-6613\(00\)01593-X](https://doi.org/10.1016/S1364-6613(00)01593-X)
- Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences*, 4(11), 417–423. [https://doi.org/10.1016/S1364-6613\(00\)01538-2](https://doi.org/10.1016/S1364-6613(00)01538-2)
- Chun, M. M., Golomb, J. D., & Turk-Browne, N. B. (2011). A taxonomy of external and internal attention. *Annual Review of Psychology*, 62, 73–101. <https://doi.org/10.1146/annurev.psych.093008.100427>
- Cowan, & Alloway. (2009). Development of working memory in childhood. In *Studies in developmental psychology. The development of memory in infancy and childhood, 2nd ed* (pp. 303–342). Psychology Press.
- Cowan, N [N.] (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *The Behavioral and Brain Sciences*, 24(1), 87-114; discussion 114-85. <https://doi.org/10.1017/s0140525x01003922>
- Endo, N., Saiki, J., Nakao, Y., & Saito, H. (2003). Perceptual judgments of novel contour shapes and hierarchical descriptions of geometrical properties. *Shinrigaku kenkyu : The Japanese journal of psychology*, 74(4), 346–353. <https://doi.org/10.4992/jjpsy.74.346>

- Fukuda, K., Vogel, E [Edward], Mayr, U., & Awh, E [Edward] (2010). Quantity, not quality: The relationship between fluid intelligence and working memory capacity. *Psychonomic Bulletin & Review*, *17*(5), 673–679. <https://doi.org/10.3758/17.5.673>
- Gazzaley, A., & Nobre, A. C [Anna C.] (2012). Top-down modulation: Bridging selective attention and working memory. *Trends in Cognitive Sciences*, *16*(2), 129–135. <https://doi.org/10.1016/j.tics.2011.11.014>
- Griffin, I. C., & Nobre, A. C [Anna C.] (2003). Orienting attention to locations in internal representations. *Journal of Cognitive Neuroscience*, *15*(8), 1176–1194. <https://doi.org/10.1162/089892903322598139>
- Hollingworth, A., Richard, A. M., & Luck, S. J [Steven J.] (2008). Understanding the function of visual short-term memory: Transsaccadic memory, object correspondence, and gaze correction. *Journal of Experimental Psychology. General*, *137*(1), 163–181. <https://doi.org/10.1037/0096-3445.137.1.163>
- Kiyonaga, A., & Egner, T. (2013). Working memory as internal attention: Toward an integrative account of internal and external selection processes. *Psychonomic Bulletin & Review*, *20*(2), 228–242. <https://doi.org/10.3758/s13423-012-0359-y>
- Klaver, P., Smid, H. G.O.M., & Heinze, H.-J. (1999). Representations in human visual short-term memory: an event-related brain potential study. *Neuroscience Letters*, *268*(2), 65–68. [https://doi.org/10.1016/S0304-3940\(99\)00380-8](https://doi.org/10.1016/S0304-3940(99)00380-8)
- Kuo, B.-C., Rao, A., Lepsien, J., & Nobre, A. C [Anna Christina] (2009). Searching for targets within the spatial layout of visual short-term memory. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *29*(25), 8032–8038. <https://doi.org/10.1523/JNEUROSCI.0952-09.2009>
- Kuo, B.-C., Stokes, M. G., & Nobre, A. C [Anna Christina] (2012). Attention modulates maintenance of representations in visual short-term memory. *Journal of Cognitive Neuroscience*, *24*(1), 51–60. https://doi.org/10.1162/jocn_a_00087
- Lepsien, J., & Nobre, A. C [Anna C.] (2006). Cognitive control of attention in the human brain: Insights from orienting attention to mental representations. *Brain Research*, *1105*(1), 20–31. <https://doi.org/10.1016/j.brainres.2006.03.033>
- Lepsien, J., Thornton, I., & Nobre, A. C [Anna C.] (2011). Modulation of working-memory maintenance by directed attention. *Neuropsychologia*, *49*(6), 1569–1577. <https://doi.org/10.1016/j.neuropsychologia.2011.03.011>

- Luck, S. J [S. J.], & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, *390*(6657), 279–281. <https://doi.org/10.1038/36846>
- Makovski, T., Sussman, R., & Jiang, Y. V. (2008). Orienting attention in visual working memory reduces interference from memory probes. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *34*(2), 369–380. <https://doi.org/10.1037/0278-7393.34.2.369>
- Matsukura, M., Cosman, J. D., Roper, Z. J. J., Vatterott, D. B., & Vecera, S. P. (2014). Location-specific effects of attention during visual short-term memory maintenance. *Journal of Experimental Psychology. Human Perception and Performance*, *40*(3), 1103–1116. <https://doi.org/10.1037/a0035685>
- Matsukura, M., & Hollingworth, A. (2011). Does visual short-term memory have a high-capacity stage? *Psychonomic Bulletin & Review*, *18*(6), 1098–1104. <https://doi.org/10.3758/s13423-011-0153-2>
- Matsukura, M., Luck, S. J [Steven J.], & Vecera, S. P. (2007). Attention effects during visual short-term memory maintenance: Protection or prioritization? *Perception & Psychophysics*, *69*(8), 1422–1434. <https://doi.org/10.3758/bf03192957>
- Nobre, A. C [Anna C.], Griffin, I. C., & Rao, A. (2007). Spatial attention can bias search in visual short-term memory. *Frontiers in Human Neuroscience*, *1*, 4. <https://doi.org/10.3389/neuro.09.004.2007>
- Paivio, A. (1971). *Imagery and verbal processes*. Holt.
- Postle, B. R., Desposito, M., & Corkin, S. (2005). Effects of verbal and nonverbal interference on spatial and object visual working memory. *Memory & Cognition*, *33*(2), 203–212. <https://doi.org/10.3758/bf03195309>
- Ricker, T. J., & Cowan, N [Nelson] (2010). Loss of visual working memory within seconds: The combined use of refreshable and non-refreshable features. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *36*(6), 1355–1368. <https://doi.org/10.1037/a0020356>
- Shimi, A., & Scerif, G. (2015). The interplay of spatial attentional biases and mental codes in VSTM: Developmentally informed hypotheses. *Developmental Psychology*, *51*(6), 731–743. <https://doi.org/10.1037/a0039057>
- Shimi, A., & Scerif, G. (2017). Towards an integrative model of visual short-term memory maintenance: Evidence from the effects of attentional control, load, decay, and their

interactions in childhood. *Cognition*, 169, 61–83.

<https://doi.org/10.1016/j.cognition.2017.08.005>

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6(2), 174–215.

<https://doi.org/10.1037/0278-7393.6.2.174>

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs: General and Applied*, 74(11), 1–29. <https://doi.org/10.1037/h0093759>