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# Effects of Concurrent Task Performance on Object Processing

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EFFECTS OF CONCURRENT TASK PERFORMANCE

ON OBJECT PROCESSING

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# DEDICATION

For Rosa Barraza, Jesus Durán, and León De la Rosa

# EFFECTS OF CONCURRENT TASK PERFORMANCE ON OBJECT PROCESSING

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ABSTRACT

Most research on visual object identification focus on the bottom-up processes of the visual *what?* and *where?* pathways. However, such research has not been able to fully account for many visual abilities (e.g., identifying an object among many other objects and across changing conditions). Neurological evidence has shown that feedback from high-level areas (i.e., top-down processing) makes object processing more efficient. However, there are no behavioral studies that have tested this. Thus, four experiments used a concurrent n-back task to occupy higher-level areas and tested its effects on visual object processing relative to a number-repetition control task.

Experiment 1 examined change detection in a flickering task, in which two versions of a picture alternated rapidly with an intervening mask. Concurrent performance of the n-back task reduced the ability to detect changes relative to the concurrent control task. Experiments 2, 3, and 4 examined the identification of pictures that were presented briefly (50, 100, or 500 ms). Overall, there were more errors and longer response times when a concurrent n-back task was performed relative to the control task. With shorter presentation times, identification was less accurate and more adversely affected by the n-back task. Experiment 3 examined short-term priming of object identification in picture naming based on a briefly presented prime picture. Short-term repetition priming effects were reliable but reduced when a concurrent n-back task was performed, but priming was not affected by prime presentation time. Experiment 4 examined long-term priming of object identification based on a briefly presented prime picture. Although the concurrent task effect indicated slower test-phase picture-naming responses for the n-back condition, this result was inconclusive given that none of the priming effects were statistically significant.

The results suggest that top-down processes affect object processing in terms of attention, which is essential to store and maintain information in working memory. It is also suggested that attention plays an important role in facilitating the process of object recognition. In terms of repetition priming, the present study confirmed the involvement of top-down processes in short-term and long-term priming effects.

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# CHAPTER 1

# INTRODUCTION

Most of the research on object recognition has focused on bottom-up processes. Bottom-up signals along the visual "what" pathway go from occipital areas (e.g., V1, V2, V4) to the temporal cortex (Ungerleider & Mishkin 1982). However, bottom-up investigations have not been able to fully account for several known phenomena in object recognition. That is, we have not been able to understand completely the process by which humans are able to identify objects among many distractors and across changing conditions or contexts.

Recently, neurological investigations have shown a strong influence of prefrontal cortex (PFC) and parietal cortex (PC) on object recognition. Despite the evidence that PFC and PC influence object recognition, it is not clear what is the nature of such influence. The dominant explanation is that PFC and PC influence object recognition in terms of attention (e.g., Kastner & Ungerleider, 2000). It has also been suggested that the influence of PFC (Bar, 2003) and PC (e.g., Xu & Chun, 2006) is in terms of perception. There is even evidence that long-term repetition priming of picture identification is reduced if areas from the PFC are disrupted by transcranial magnetic stimulation (TMS) (Wig, Grafton, Demos, & Kelley, 2005). These views have only been explored using brain-imaging techniques, case studies of patients with prefrontal damage, and neurological studies with animals. As far as we know, the function of top-down processes in object recognition has not been explored using behavioral experiments with humans.

Therefore, my dissertation goal was to test the function of top-down processes on object processing by developing appropriate behavioral tasks and manipulations of stimuli and instructions. Using behavioral procedures not only opens a range of possibilities to explore but it

also reduces the time and the costs of testing. Four experiments were performed. Experiment 1 and 2 tested the influence of top-down processes on change detection and object recognition respectively. Experiments 3 and 4 explored the function of top-down processes on short-term and long-term picture repetition priming, which is facilitation based on previous experience with an object.

## 1.1 Bottom-Up Accounts of Object Recognition

*Neurological Support*

There is substantial evidence accounting for object recognition from a bottom-up perspective. This evidence suggests that areas responsible for object recognition are organized hierarchically (e.g., Bullier, 2001). The object recognition or "what" pathway starts in V1 proceeds to V2, and then to V4 (Felleman & Van Essen 1991; Ungerleider & Mishkin 1982), to end in the inferotemporal cortex (Ungerleider & Mishkin 1982). Cells in V1 and V2 have small receptive fields with orientation selectivity (Hubel & Wiesel, 1962; 1968). Some neurons in V2 are more active in the presence of complex stimuli such as curvatures and corners than to simpler stimuli (e.g., lines) (Anzai, Peg, & Van Essen, 2007). Area V4 also shows selectivity for angles and curvatures, and variation in response mainly depends on changes in orientations of angles and curves (Gallant, Connor, Rakshit, Lewing, & Van Essen, 1996; Kobatake & Tanaka, 1994; Pasupathy & Connor, 1999). Also V4 tends to respond more to convex features in contrast with concave features (Pasupathy & Connor, 1999). The elements processed by V4 are considered to have a medium level of complexity (Bar, 2003).

The information from V4 is sent to the anterior region of inferior temporal cortex. There, it is processed and sent to other cortical areas such as the perirhinal cortex, the prefrontal cortex, the amygdala, and the striatum (Tanaka, 1993). Tanaka (1993) was able to show that the

organization in the anterior region of inferior temporal cortex is modular, resembling the organization of V1. Such organization produces less susceptibility to changes in the environment and an accurate representation. Also, he showed that cells in the anterior region of inferior temporal cortex were sensitive to complex stimuli. That is, the stimuli needed to be more complex than the ones that are able to activate neurons in V1 (e.g., more complex than orientation, size, color and simple structure). There is also evidence that the inferotemporal cortex has neurons sensitive to face patterns (Perrett, Rolls, & Caan, 1982).

*Two Bottom-Up Models of Object Recognition*

*Recognition by Components Model.* According to Biederman, the transformation of each perceived object into a 'view-point invariant' structure reduces its variability and facilitates object identification (1987). The process of forming these structures begins with a simple sketch of a perceived object. Following that, the perceptual system detects the 'non-accidental properties' of such object (i.e., whether the contours are straight or curved, and whether they are parallel in relation to other contours), and then matches these properties with a corresponding 'geon'. Thus, a general structure of the object is formed and compared against memory representations of different objects.

There is some neurological evidence suggesting that this is the case (Biederman, 2007). For example, the evidence that inferior temporal cortex shows a preference for invariant complex features (Tanaka, 1993) suggests that it is detecting geons. Also, inferior temporal cortex cells in macaques showed more modulated firing when there was a change in 'non-accidental properties' (which are diagnostic in identifying geons), than when there was a change in 'metric properties' (i.e., relative characteristics of objects not diagnostic of geon identification) (Kayaert, Biederman, & Vogels, 2003). A different experiment showed that neurons within inferior

temporal cortex tended to respond to specific parts of an object (Tsunoda, Yamane, Nishizaki, & Tanifuji, 2001). Recall that in Biederman's theory, these parts are represented by geons. In general, these findings suggest that there is some neurological evidence supporting the idea that geons are automatically used in object recognition.

Biederman (2007) suggests that inferior temporal cortex is not only tuned to detect complex stimuli but it also automatically detects 'structural descriptions', which are the specific relations among the parts. In other words, the automatic detection of the object's parts occurs in parallel with detection of the different relations among them. He found that the intraparietal sulcus is sensitive to the relations among parts of an object (Hayworth & Biederman, 2005), consistent with the known role of the dorsal visual "where" pathway in processing the spatial relations among distinct objects (Ungerleider & Mishkin, 1982).

Hummel (Hummel, 2001; Hummel & Biederman, 1992) developed a computational model based on the recognition by components model. It consisted of a hierarchical network that takes as input a line drawing of an object and produces as output the identity of the object. First, the network detects the 'nonaccidental properties' of the object. From there, it detects the geons conforming the object and the relationships among them (i.e., their structure). They also incorporated synchronized oscillatory activity to solve the binding problem within the system. That is, it solved the problem of how to encode the arrangement of the geons. The simulation of the computational system consisted of a training and a test stage. During training, the system was exposed to 10 different figures, and only one view of each object was presented. At test, different versions of the figure presented at training were shown (i.e., they were moved to a new position, the size was altered, they were rotated, or their mirror equivalent was presented). The computational model was able to identify the changed figures with high accuracy. This supports

the ability of the model to identify an object even when its irrelevant characteristics are changed. One of the main limitations of this model is that it was only able to recognize very simple images (e.g., few geometrical shapes forming one figure), and only when objects were presented in isolation.

*A Quantitative Model of Immediate Visual Recognition*. Serre et al. (2007) have developed a competing quantitative account of object recognition. According to them, object recognition is a 'tradeoff' between selection and invariance. On one hand, the system needs to detect relevant changes to recognize an object. On the other, the system needs to ignore irrelevant features such as visual noise. In order to test this, they propose a computerized hierarchical model (which goes from simple to complex) in which at each stage there are selective and invariant mechanisms. They regard selective cells as simple (S) and invariant as complex (C). In stage one, $S_1$ cells detect simple changes, sending the information to $C_1$ cells. $C_1$ cells average all the input from $S_1$ cells and send the information to $S_2$ cells in the next stage of the process, which in turn will send the info to $C_2$, and so on.

There is neurological evidence that supports this view. For example, complex neurons are present in V1 (e.g., Mahon & DeValois, 2001). This suggests that there are invariant cells even in V1. Also, V2, V4, and inferior temporal cortex each have cells showing a range of selectivity from relatively simple to relatively complex (e.g., Tanaka, 1996). The evidence mentioned earlier that higher stages within the ventral visual pathway are sensitive to complex visual patterns supports the hierarchical organization proposed. Serre's computational model was able to show scale and position invariance for new objects. Because of this invariance, having experience with different views of the same object becomes unnecessary for recognition. Also, Serre's computational model was compared with human performance, in an animal vs. non-

animal classification task and no significant differences were found between the model and behavioral data. However, this was only true when humans were not able to use the aid of top-down processes (Serre et al., 2007).

*Differences Between the Two Bottom-Up Models*

One of the main discrepancies between the two models is that Serre et al. (2007) denies the necessity of a segregation step for recognition, thus implying that geons are not necessary to recognize objects. Recall that Biederman's model has a segregation step where geons are a critical step for object recognition. The second main discrepancy between the two models is that Biederman assumes that structure is integrated with geon detection (2007). In contrast, for Serre et al. (2007) the complex features detected by the ventral-visual pathway are 'unbound features', which is consistent with cognitive theories of pre-attentive features (Treisman & Gelade, 1980). In terms of attention, Hummel and Biederman (1994) suggested that attention is only necessary to ignore attributes that do not belong to an object. While for others attention may be necessary to unify the different attributes of an object (Tresiman & Gelade,1980; Wheeler & Treisman, 2002).

While a model like the one proposed by Biederman (1987) may not require the intervention of top-down processes, Serre et al. (2007) affirm that their computerized model will benefit from top-down processes. Following Bar (2003), I will argue that both models could benefit from top-down processes. First, it still not clear how humans are able to recognize an object so quickly, when they have a memory for a very large number of items. The problem is, how can humans determine that an object is a known member of a known object category when there are so many possibilities (memories of previous objects perceived) to compare it against.

The other problem refers to the human ability to immediately recognize a target object when there are many distracters (Serre et al., 2007). How are humans able to disregard irrelevant objects to concentrate on the relevant ones? It seems that top-down processes would help to solve such problems. For example, top-down processes may send relevant information to inferior temporal cortex, reducing the possibilities of what the perceived object could be (see next section for more information) (Bar, 2003). It is also possible that top-down processes functioning as attention may direct bottom-up processes to concentrate on what is regarded as relevant, helping to identify a target among distracters (Serre et al., 2007).

Based on these questions, the following sections will focus on object recognition from a top-down perspective. Top-down influences can be defined either neurologically or psychologically, and sometimes these two definitions do not agree (Frith, 2005). According to Frith (2005), a top-down neurological perspective refers to the influence of feedback signals sent from parts of the brain involved in high-level processing (e.g., PFC or PC) to parts of the brain involved in lower level processing (e.g., low-level visual areas). In contrast, a psychological top-down perspective refers to specific experimental situations in which participants focus their attention on some stimuli while ignoring others (bottom-up psychological situations are when stimuli are passively perceived). A specific example in which these two definitions do not agree is that, binding the different characteristics of an object requires feedback from the parietal cortex (i.e., neurological top-down process), but there is no psychological control mechanism that can stop such processes (i.e., a psychological top-down process) (Frith, 2005). Although the individual cannot intentionally stop his or her own neurological top-down processes, it is possible to use psychological tasks to disrupt such processes when both the top-down processes and the psychological tasks require the same neurological resources. While the present study

takes into account mainly a neurological top-down perspective, a psychological perspective is also included, because the concurrent tasks required in the four experiments used psychological top-down processes according to this definition, with the objective of disrupting the neurological top-down processes.

## 1.2 Evidence for Top-Down Processing in Object Recognition

### *Neurological Support*

Anatomical evidence supports the possibility that neural feedback influences object recognition (e.g., Rempel-Clower & Barbas, 2000). Networks in frontal and parietal cortex seem to be responsible for such top-down processes (e.g., Kastner & Ungerleider, 2000). There is also evidence that top-down signals have a faster effect on low-level visual areas (i.e., V1 and V2) than the horizontal signals within the visual system that help to integrate lower level information (e.g., Bullier, 2001). Also, visual attention via top-down processes can bias neural responses in primary visual areas (Kastner & Ungerleider, 2000) by increasing the responses of cells responsible for capturing what is attended (e.g., Spitzer, Desimone, and Moran, 1988), filtering out irrelevant information (e.g., Raynolds, Chelazzi, & Desimone, 1999), increasing baseline activity before the to-be attended object is presented (e.g., Luck, Chelazzi, Hyllyard, & Desimone, 1997), and enhancing visual contrast (see Kastner & Ungerleider, 2000). The influence of top-down processes in visual processes is also supported by the fact that human patients with prefrontal damage present difficulties in recognizing images when recognition is made difficult, for example by occluding or scrambling the image (e.g., Richer & Boulet, 1999). Moreover, electrophysiological studies support the conclusion that PFC is involved in object categorization (e.g., Freedman, Riesenhuber, Poggio, & Miller, 2001). All these studies suggest that top-down processes are central in object recognition. However, there is still no agreement

whether the exact role of top-down processes in object recognition is in terms of attention or perception.

*Top-Down Attentional Involvement in Object Recognition*

Kastner and Ungerleider (2000) claimed that top-down processes influence object recognition in terms of attention only. The fact that top-down processes are active before (Kastner & Ungeleider, 2000) or after (Supèr, 2005) the target object is presented supports this claim, suggesting that top-down processes do not carry but regulate visual information in the primary visual areas. Such processes are also involved in the maintenance of the attended information for short time periods (Schmidt, Vogel, Woodman, & Luck, 2002). That is, top-down attentional processes actively participate in visual working memory.

The areas (i.e., prefrontal and parietal) associated with top-down attentional processes are closely associated with working memory (Kastner & Ungerleider, 2000). Evidence from the change blindness literature (Rensink, 2002) also supports this view by showing that visual information has 'limited spatial and temporal coherence' prior to focused attention. According to Rensink (2002) attention is not only necessary to bind visual information, but it needs to be sustained to keep the binding intact. This suggests that without sustained attention there is no visual working memory.

*Top Down Perceptual Involvement in Object Recognition*

Moshe Bar (2003) presented a model attempting to explain the role of PFC in object recognition in terms of perceptual processes. Low frequency visual information is projected from early visual areas to PFC (Rempel-Clower & Barbas, 2000), possibly by the magnocellular pathway (Bar et al., 2006). PFC areas use such information to form a general sketch of the perceived object. Such general information is sent to inferior temporal cortex where it is used as

an ‘initial guess’ of what the object can be and it is compared against the more detailed object analysis performed by the bottom-up processes (Bar, 2003, 2006).

The orbital prefrontal cortex is the specific area that sends the information to inferior temporal cortex (Bar, 2006). There is some evidence that this area analyzes visual information (e.g., Szatkowska, Grabowska, & Szymanska, 2001). It is also associated with guessing, hypothesis testing, and expectation generation (e.g., Petrides, Alivisatos, & Frey, 2002). Bar (2006) was able to show that visual information is active 50 ms earlier in the orbital PFC than in inferior temporal cortex. However, this was only true when the stimuli consisted of images with low spatial frequency. These findings are strong support for Bar’s model.

*PFC Involvement in Picture Priming*

Repetition priming in picture identification refers to the facilitation obtained the second or subsequent times an item is processed. Such facilitation is shown in reductions of reaction time (e.g., Bartram, 1974) and neural responses (e.g., Ghuman, Bar, Dobbins, & Schnyer, 2008). More specifically, occipitotemporal cortex shows reductions in activity as a result of repeated exposure to objects (van Turennout, 2003). Neurons within the inferotemporal cortex show firing reductions when animals perform repeated visual tasks (Ringo, 1996). Ventral temporal cortex and frontal cortex also show reduced neural response using fMRI measures (Eriksson, Larsson, & Nyberg, 2008; Grill-Spector, Henson, & Martin, 2006). Interestingly, MEG measures suggest that priming effects in ventral temporal cortex arise only after feedback from frontal cortex (Grill-Spector et al., 2006).

Moreover, the interaction between top-down and bottom-up processes seems to be necessary in long-term repetition priming (Ghuman, Bar, Dobbins, & Schnyer, 2008). There is some evidence that disrupting the left inferior frontal gyrus by using TMS at encoding largely

reduced behavioral (response times) and neural long-term priming effects in picture identification (Wig et al., 2005). They also showed that early perceptual priming was unaffected by TMS suggesting that priming can be separated into conceptual and perceptual areas. Behavioral studies with bilinguals also have shown that repetition priming in picture naming is based in part on speeded object identification processes and part on word retrieval and production (e.g., Francis, Corral, Jones, & Sáenz, 2008). The present study mainly focused on object identification processes.

Stankiewicz, Hummel, and Cooper (1998) were not able to find long-term priming effects when they got participants to ignore targets by having them name another object presented simultaneously. This result suggests the central role of attention in long-term priming. In another experiment they showed the influence of attention in short-term priming. Attended and ignored items both produced significant short-term priming. However, ignored items showed smaller priming effects than attended items, indicating that attention is important in short-term priming. As mentioned earlier, attention is strongly associated with top-down processes, specifically with PFC and PC. Thus, these last two behavioral experiments not only support the involvement of top-down processes in long-term priming but also in short-term priming. In contrast, Gabrieli et al. (1999) were not able to find a reduction in long-term priming for picture naming when attention was divided by holding in mind a ‘digit-letter string’ as they named a picture. Such counterintuitive findings may be the result of methodological differences. For example, it may be the case that attention was not truly divided as participants were exposed to the picture, and as a result priming was not affected.

## 1.3 Present Study Justification

The common idea across the four experiments performed was to test the impact of top-down processes across different perceptual tasks. In order to do that, participants were asked to perform an n-back task concurrent with the main task (i.e., change blindness, object recognition, and repetition priming) in each experiment. The intention was to 'steal' resources from high-level processing areas (e.g., PFC and PC) with the n-back task, and test whether this would affect performance on the main tasks. In general, the n-back task consists of comparing a specific item with another item presented *n* trials before. For example, a 2-back task requires comparing whether a number is same or different to another number that appeared two places back.

The n-back task was chosen as secondary task based on previous research that shows its strong association with working memory and executive functioning (Jonides et al., 1997). Moreover, a quantitative meta-analysis on neuroimaging studies showed that lateral and medial posterior parietal cortex, lateral and medial premotor cortex, dorsolateral and ventrolateral prefrontal cortex, and frontal poles are the main areas involved in the n-back task (see Owen, McMillan, Laird, & Bullmore, 2005). These areas are correlated with attention and working memory processes (Owen et al., 2005). Concurrent n-back and antisaccade task performance also support the involvement of PFC in the n-back task (Mitchell, Macrae, & Gilchrist, 2002). That is, human patients with prefrontal damage (Guitton, Büchtel & Douglas, 1985), and normal humans performing an n-back (Mitchell et al., 2002) both show a detriment in saccade control. Thus, these neurological and behavioral evidence support the involvement of specific high-level brain areas (e.g., PFC) in the n-back task.

It is possible that the impact of the n-back on the primary tasks is produced merely by the act of doing two tasks simultaneously. In order to avoid this potential confound, a number

repetition activity was chosen as a control task. Just like in the n-back task participants had to listen to numbers and vocally report answers. However, the main difference between the two was that the n-back task required the use of working memory resources while the number repetition task did not. In this way, while participants performed two tasks simultaneously in both test and control conditions, only the former will require the use of top-down processes. Previous evidence has shown that a number repetition task does not require significant use of top-down processes (Robertson, Hager, & Heron, 1994). Specifically, it was shown that a number repetition activity produced fewer errors in an antisaccade task than an arithmetic task. As mentioned before, antisaccade tasks are strongly associated with executive functions (Mitchell et al., 2002). Therefore, the number repetition task seems to have little effect on executive functions (Robertson, et al., 1994).

Four experiments were performed. Experiments 1 and 2 tested whether top-down processes influences change detection and object recognition respectively. Experiments 3 and 4 explored the function of top-down processes on picture repetition short- and long-term priming respectively. It has been suggested that attention plays an important top-down role in object recognition (e.g., Sùper, 2005; Serre et al., 2007). Specifically, attention seems essential in detecting a specific object among many other objects. It has even been suggested that PFC aids in the perceptual recognition of the object (Bar, 2003). Thus, for Experiment 1, participants performed a variation of a change detection task, while their top-down resources were used in an n-back task. It was tested whether change detection is reduced or slowed when the top-down resources are allocated to an alternative task. For Experiment 2, the effects of top-down processes on object identification were tested. Participants used their top-down resources in n-back task as they tried to identify pictures. Similarly, for Experiment 3 and Experiment 4 it was

tested whether priming effects are reduced, if during the encoding phase top-down resources are used in an n-back task. This seems plausible since Wig et al., (2005) were able to show that disrupting the PFC using TMS reduced neural and behavioral indicators of facilitation effects in a repetition-priming task.

# CHAPTER 2

# EXPERIMENT 1

Previous findings show that the dorsolateral PFC is active during the performance of working memory tasks (Owen, 2000). Lesions to this area are also associated with impairments in directing attention to relevant information (Dias, Robbins, & Robers, 1996). Thus, for Experiment 1 we tested behaviorally whether PFC processing is necessary for change detection in complex photographs. Participants performed simultaneously a change detection task using a flickering paradigm (based on Rensink, O'Regan, & Clark, 1997) and a secondary task (i.e., either an n-back or a number repetition task). The change detection task consisted of the following. Within a trial, two similar photographs alternated rapidly for 20 cycles. Participants had to detect a specific difference between the two pictures. It was predicted that participants would take longer or fail to detect changes when they performed a simultaneous n-back task than when they performed a number repetition task. If top-down processes are necessary for detecting the change, then participants would show more errors in the test condition (i.e., n-back task) then in the control condition (i.e., number repetition task).

## 2.1 Methods

### *Participants*

Forty university students were recruited for this experiment from the University of Texas at El Paso and from the Universidad Autónoma de Ciudad Juárez. There were 20 women and 20 men. The average age was 24.6 years. One participant was replaced for not following the task instructions. Participants were native speakers of either English or Spanish, and received course credit for participating.

### *Apparatus*

Stimuli were presented on the monitor of a Macintosh G4 computer using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). A PsyScope button box (New Micros, Dallas, TX) was used to record participants' responses.

*Design*

Experiment 1 had a one-way repeated-measures design. The independent variable was the secondary task, (1) a PFC task condition (performing an n-back task) and (2) a control task (repeating numbers). Response times and error rates were used as the dependent variables.

*Materials*

Eighty pairs of photographs were used. Each pair consisted of a photo that depicted a complex scene, and a replication of this photo that was edited by changing a specific object or feature. An example is given in Figure 1. Forty pairs of photographs were used for the n-back condition, and the other 40 were used for the number repetition condition. The assignment of pairs to conditions was counterbalanced across participants. Eighty auditory strings of numbers (from 1 to 5) were used for the secondary tasks.

*Procedure*

Experiment 1 consisted of one session and lasted about 45 minutes. The conditions were blocked by the secondary task condition, with 4 practice and 40 experimental trials for the n-back task and 4 practice and 40 trials for the number repetition task. The presentation order of the two blocks was counterbalanced across participants.

For the primary task, on each trial participants viewed two alternating versions of the same photo (for a maximum of 20 times each), and they had to judge what was different between them. They had to press a button the moment they detected the change. While they were trying to detect the change, participants performed a secondary task. A sequence of numbers was

presented, and participants had to perform either an n-back task or a number repetition task. Numbers were presented in either English or Spanish depending on the dominant language of participants. For the n-back task, they had to mentally compare each number they heard with two numbers back and report aloud whether the numbers were the same or different. For the number repetition task they only had to repeat the numbers they heard throughout the trial. They stopped performing the secondary task the moment they detected the change between the pictures or when the trial ended. Also, after they indicated detecting the change by pressing a button, they had to report the difference between the two photos presented (if they detected one).

Figure 2 shows a visual representation of an experimental trial. At the beginning of each trial a 'plus' sign appeared on the screen until participants pressed the space bar to start, then the screen went blank for 3000 ms. At 1000 ms, the first digit was presented. The $2^{nd}$, $3^{rd}$, and $7^{th}$ digits began 2500 ms after the onset of the previous digit respectively. The $4^{th}$, $5^{th}$, and $6^{th}$ began 2000 after the onset of the previous digits. (On average, there were 2250 ms after the onset of each digit). Last digit onset was 14500 ms after initiation of trial.

A visual mask appeared 3000 ms after the trial began and remained on the screen for 1000 ms, then the first photo appeared. The purpose for showing the visual stimuli 3000 ms after the auditory stimuli allowed participants to occupy themselves with the alternative task before beginning to search for the visual change. The first photo appeared for 240 ms, then a mask appeared for 80 ms, then the second photo appeared for 240 ms, then the mask appear again for 80 ms and so on. This cycle was presented continuously up to 20 times unless participants were able to detect the change before the end of the trial (up to 16800 ms after the start of the trial). Participants were instructed to press a button the moment they detected the change. Response times were measured from the onset of the first picture to the button press response. The button

press stopped the cycle, and one of the two photos appeared on the screen. At this point participants could point directly to the picture and explain to the experimenter where and/or what was the change. The complete trial lasted around 20 sec.

## 2.2 Results

The dependent variables showed high variability across items. Therefore two types of analyses were done. The first analysis was the standard analysis that treats participants as a random factor with performance averaged across items. The second analysis was an item analysis in which performance for each item was averaged across participants and items were treated as a random factor. Error rates are often transformed using an arcsine function to accommodate the multiplicative nature of probabilities. Given that this transformation did not change the main conclusions of the present study, the untransformed error values are reported for Experiments 1, 2, 3, and 4. However, arcsine transformed error rates are reported in the appendix. Response times were somewhat skewed. However, it was not necessary to correct for skew in the inferential analyses, because of the central limit theorem, given that there were more than 12 participants per condition and that the use of a within-subjects design ensured equal sample sizes for the different experimental conditions (Keppel & Wickens, 2004).

### *Error Rates*

A trial was considered to have a response error when participants pressed the button to indicate that a change was detected but reported incorrectly or were not able to report the change between two pictures. Sometimes participants were not able to vocally report what was the change, but they were able to point to the area where the change happened. These types of responses were not considered errors. An analysis was performed for errors in which participants pressed the button but they were not able to correctly report the change, showing that there was

no difference between the n-back (*M* = 2.2%, *SD* = 3.1) and the number repetition (*M* = 1.6%, *SD* = 3.3) conditions, $t(39) = 1.57$, $p = .124$. The item analysis also showed no difference between the n-back (*M* = 2.2%, *SD* = 4.2) and the number repetition (*M* = 1.6%, *SD* = 4.0) conditions, $t(39) = 1.22$, $p = .228$.

A more common error type was simply running out of time to detect the change. That is, the change was not detected within the time allocated for the trial. Therefore, this error type is thought to reflect timing rather than a mistaken identification. A dependent samples t-test was performed to compare time-out error rates in the n-back versus the number repetition conditions. The n-back condition (*M* = 16.4%, *SD* = 8.7) showed significantly more time-out errors than the number repetition condition (*M* = 10.2%, *SD* = 5.2), $t(39) = 4.81$, $p < .001$. The item analysis also showed significantly more time-outs for the n-back (*M* = 16.4%, *SD* = 20.6) than the number repetition (*M* = 10.2%, *SD* = 16.4) conditions, $t(39) = 5.26$, $p < .001$. Note that the variability was larger for the item analysis than for the participant analysis.

*Response Times*

For the response time analysis, only correct responses were included. Responses were considered correct when participants reported detection of the change by pressing a button and by correctly reporting what the change was. Timing was relative to the onset of the first photograph. A dependent samples t-test was performed on response times for the n-back condition (*M* = 4368.8, *SD* = 660) and the number repetition condition (*M* = 4274, *SD* = 536). The difference between the two was not significant $t(39) = .08$, $p = .453$. An item analysis was performed. One item was excluded from the analysis because only three participants detected its change. A dependent samples t-test showed longer response times for the n-back condition (*M* =

4740.2, *SD* = 1993) than for the number repetition condition (*M* = 4470.5, *SD* = 1894), $t(78) = 2.4$, $p = .019$.

## 2.3 Discussion

As expected, participants detected fewer changes and were slower in the n-back than in the number repetition condition, based on the response times and proportions of trials for which the time to detect a change ran out. These findings confirm the predictions of top-down processing involvement in change detection tasks. As mentioned earlier, top-down attentional processes are involved in visual working memory (Kastner & Ungerleider, 2000). Hence, the present findings support the involvement of visual working memory in change detection tasks. Specifically, it supports the idea that sustained attention is necessary to maintain visual information in working memory because attentional disruptions from the n-back task worsened performance.

Rensink (1997) showed that changes in areas of central interest were identified faster than changes in areas of marginal interest. He then suggested that such differences are the result of more attentional attraction towards areas with ‘high-level interest’. However, it is also possible that changes in areas of central interest also require less attentional resources because they are processed faster. Thus, it is likely that a task such as the n-back may have less impact in changes occurring in central interest areas than in changes occurring in marginal interest areas. Further research is required to statistically test differences between pictures with marginal and central interest in a concurrent performance of a change-detection and an n-back task.

# CHAPTER 3

# EXPERIMENT 2

Experiment 2 tested behaviorally whether top-down processes are necessary for object recognition. Participants performed an object recognition task and a secondary task (i.e., either an n-back task or a number repetition task) simultaneously. Within each trial, pictures were presented briefly (500 ms or less). Participants had to recognize each picture while they performed a secondary task and verify that recognition by naming it afterwards. It was predicted that participants would show slower response times and higher error rates in recognizing pictures when they performed a simultaneous *n-back* task than when they performed a simultaneous number-repetition task.

Previous research (e.g., Bar, 2003) suggests that detecting the effects of PFC on object recognition is more likely if the images are difficult to perceive. To vary the level of difficulty in perceiving the images, pictures were presented for different periods of time (50, 100, 500 ms). This allowed us to test whether the PFC impact is greater for briefly presented images than for images presented for longer time periods.

## 3.1 Methods

### *Participants*

There were 48 participants (29 women and 19 men). All were university students from the University of Texas at El Paso. The mean age was 20 years. Participants were native speakers of English or Spanish and they received course credit for participating. Three people were replaced because the computer crashed during the experiment. Three more were replaced because they correctly named less than three pictures in the 100 ms condition. Seven participants

correctly named less than three pictures within the 50 ms condition. However, those participants were not replaced.

*Apparatus*

The present experiment used the same equipment in Experiment 1.

*Design*

Experiment 2 had a 3 (presentation time) X 2 (secondary task) repeated-measures design. The presentation time of each picture was either 50 ms, 100 ms, or 500 ms. The secondary task was performing either a PFC task (i.e., an n-back task) or a control task (i.e., number repetition task). The dependent variables were response times and error rates for picture recognition.

*Materials*

The critical stimuli were 126 digitized drawings of common objects. These pictures were randomly assigned to 6 groups of 21 pictures. The assignment of picture sets to conditions was counterbalanced. Also, 126 auditory sequences of 7 numbers (from 1 to 5) were used for the secondary tasks, with 21 auditory sequences randomly assigned to each condition. A native speaker of English and a native speaker of Spanish recorded the numbers. Since many of the participants were either English or Spanish dominant, we wanted them to hear the numbers in their dominant language. The reason for this was that it is very difficult to perform mental arithmetic in the non-dominant language.

*Procedure*

The experiment was completed in a single one-hour session and participants were tested individually. The trials were blocked by the secondary task (doing either the n-back or number repetition task concurrently). At the beginning of the n-back condition block, 5 practice trials were given in which participants had to identify a picture presented for 500 ms while performing

an n-back task. At the beginning of the easier number repetition condition, only 3 practice trials were given, also with a 500 ms presentation time. Within each secondary task block, the 63 experimental trials were further blocked by the presentation time (pictures were shown for either 50, 100, or 500 ms). Participants were warned of the speed of presentation before each change. The orders of the different concurrent task and presentation time blocks were counterbalanced to control for order effects.

On each trial, a picture was presented and participants had to report whether they were able to identify the picture or not. They had to press the 'yes' button if they were able to identify the picture or not press anything if they did not see the picture. At the end of each trial, they reported the name of the picture. At the same time as they tried to identify the pictures, participants had to perform an n-back task or a number repetition task with numbers presented auditorially. For the n-back task, they had to compare mentally each number they heard with the number they heard two numbers back and report aloud whether each number was the same or different. For the number repetition task, they just had to repeat immediately each number that they heard.

Figure 3 illustrates what happened on each trial. At the beginning a 'plus' sign was presented on the computer screen as a fixation point. Participants pressed the space bar to start the trial. At this point, the screen went blank and participants began to hear a sequence of seven digits across a 13300 ms interval. The onsets of the numbers were 2 sec apart. This spacing was meant to allow sufficient processing time to perform the n-back task accurately. For the n-back task, participants compared these numbers mentally and reported aloud if the corresponding numbers were the same or different. For the control task, participants repeated aloud each of the numbers they heard immediately after they heard it.

Each picture appeared at one of three different times after the 3rd, 4th, or 5th number across the different trials. The reason for varying the onset time was to prevent participants from predicting at what moment each picture would appear. Pictures were presented until the 3rd number because that was when participants start responding to the n-back *task*, allowing participants to be engaged in it before seeing the pictures. The assignment of each picture to a specific onset time was counterbalanced across the different trials. Pictures were presented for 50 ms, 100 ms, or 500 ms. A mask of 250 ms preceded and succeeded each picture. This mask was constructed with scribbles resembling some of the lines and curves from the drawings used (see Figure 3), and its purpose was to increase recognition difficulty. When the picture appeared, the participants reported whether they were able to recognize the picture by pressing the 'Yes' button as quickly as possible or by not pressing anything otherwise. After that, the screen was blank for the remaining time during which the numbers were presented. At the end of the trial, when the fixation sign '+' appeared again, participants had to report aloud the name of the presented picture.

## 3.2 Results

*Error Rates*

As mentioned before, participants had to report the name of each of the pictures presented. Answers were considered erroneous when they failed to report the name (e.g., saying 'don't know'), or said an incorrect one, or when they failed to press the button. Trials on which participants pressed before the picture appeared were not considered errors if the picture was named correctly. Error rates are presented in Table 1.

A 3 (presentation time) X 2 (secondary task) ANOVA was performed on error rates. First, there was a significant main effect of presentation time, $F(2, 94) = 265.40$, $MSE = 9.401$, $p$

$< .001$, showing that error rates decreased with longer presentation time. Planned comparisons showed that there were more errors for the 50 ms condition than for the 100 and 500 ms conditions, [$F(1, 47) = 263.215$, $MSE = 8.883$, $p < .001$; $F(1, 47) = 394.892$, $MSE = 11.979$, $p < .001$]. Also there were more errors for the 100 ms condition than for the 500 ms condition, $F(1, 47) = 56.807$, $MSE = 7.343$, $p < .001$. Participants showed significantly more errors in picture identification when they performed the n-back task than when they performed the number repetition task, $F(1, 47) = 42.561$, $MSE = 6.720$, $p < .001$. This was true for the 50, 100, and 500 ms conditions, [$t(47) = 5.244$, $p < .001$; $t(47) = 15.631$, $p < .001$; $t(47) = 5.453$, $p < .001$]. There interaction between secondary task and presentation time was not significant, $F(2, 94) = 2.193$, $MSE = 3.706$, $p = .117$.

*Error Types*

Although no hypotheses were made a priori about the nature of the errors that would occur, interesting observations by the experimenters led to an examination of error types. About 17.9% of the trials (68.1% of error trials) had no attempt to state what picture had appeared (i.e., don't know responses). These errors or identification failures were more common in the n-back ($M = 23.28\%$) than in the number repetition condition ($M = 13.96\%$), $t(47) = 9.487$, $p < .001$. In fact, although not recorded systematically by the experimenters, on many occasions while performing the n-back task, participants questioned whether a picture had in fact been presented. On about 0.8% of all trials (3.1% of error trials) participants correctly identified the object but failed to press the button. For this type of error there was no difference between the n-back ($M = 0.83\%$) and the number repetition conditions ($M = 0.86\%$), $t(47) = .093$, $p = .926$.

On about 7.6% of all trials (28.8% of error trials), participants gave responses that were unacceptable as interpretations of the stimulus pictures. For these types of errors, there were no

differences between the n-back ($M$ = 8.17%) and the number repetition condition ($M$ = 7.94%), $t(47) = .276$, $p = .784$. Some errors clearly referred to pictures presented on recent trials and were not perceptually related to the target stimulus (e.g., saying *pumpkin* when a door was presented or mountains when a spider was presented). Some errors were items that were closely related functionally or conceptually as well as visually (e.g., saying *hand* for a glove, *broom* for a mop, or saying *fish* for a whale), so it was unclear what was the source of the error. This type of error is common in picture naming experiments with pictures presented in full view.

However, an error type not typically seen in picture naming studies also emerged in the 50 and 100 ms conditions. Several error responses were objects that shared general shape characteristics but not fine-grained details with the actual stimulus object. For example, multiple participants identified the skirt as a cone, the monkey as a man, boy, or person, the binoculars as bottles, the telescope as a pencil, the iron as a boat or ship, or the aquarium (filled with water and fish) as a box. The classification of error types for several other items was ambiguous (because of conceptual or functional similarity or because the visual errors were common in normal picture naming. However, these errors were clearly more frequent for the 50 ms and for the 100 ms conditions than for the 500 ms condition.

*Response Times*

Response times were analyzed using only correctly identified pictures (i.e., they were identified on button-press and correctly named). If participants did not pressed the button when a picture was presented or if they did not say the correct name of the pictures presented, the trials were removed. Also, response times less than 200 ms, more than 3000 ms, or three standard deviations away from the mean of the condition were removed as outliers (this procedure

removed trials on which they pressed the button before the picture appeared). Response times are presented in Table 1.

A 3 (presentation time) X 2 (secondary task) ANOVA was performed on identification response times. There was a main effect of presentation time, $F(2, 92) = 4.324$, $MSE = 10049$, $p = .016$. Planned comparisons showed no significant differences between the 50 and the 100 ms condition or for the 50 and the 500 ms conditions [$F(1, 46) = 3.237$, $MSE = 9884$, $p = .079$; $F(1, 46) = 1.203$, $MSE = 10711$, $p = .278$]. However participants were faster for the 100 ms condition than for the 500 ms condition, $F(1, 46) = 9.480$, $MSE = 9354$, $p = .003$. The main effect of secondary task was not significant, $F(1, 46) = .849$, $MSE = 14937$, $p = .362$. Individual comparisons showed that while there were no significant differences between the n-back and the control conditions for the 50 and the 100 ms [$t(46) = .663$, $p = .511$; $t(47) = 1.312$, $p = .196$], the difference in the 500 ms condition approached significance, $t(47) = 1.993$, $p = .052$. The 500 ms condition effect suggests that participants were slower to identify pictures when they performed the n-back than when they performed the number repetition condition. The interaction between presentation time and secondary task was not significant, $F(2, 92) = 1.798$, $MSE = 8858$, $p = .171$.

### 3.3 Discussion

For all presentation times, there were significantly more errors for the n-back condition than in the control condition, suggesting that disrupting top-down processes reduces the ability to identify objects. Response times only showed an effect approaching significance for the 500 ms condition. For the shorter presentation times (50 and 100 ms) the effects were not even close to significant possibly because their scores were highly variable. This variability was the result of fewer correct trials within these two conditions, given that only trials with correctly identified

pictures went into the analysis. It is also possible that with more participants these effects would be more stable. An analysis with the combined data of Experiments 2, 3, and 4 will be presented in a later section.

In relation to error types, within the 50 and 100 ms conditions participants sometimes were not aware of the presentation of the target picture. That is, they reported that they did not see any picture (rather than reporting that they saw a picture but were not able to identify what it was). This suggests that disruption of top-down processes sometimes produced a brief blind period, even when participants knew ahead of time that a picture was going to appear. Another interesting type of error was reporting the name of an object that is similar in terms of shape to the presented object (e.g., *men* for monkey). This specific type of error suggests that participants were not able to capture the details of the pictures quickly enough for an accurate identification.

There were significant effects of presentation time in error rates, with higher error rates for shorter presentation times. In the response time analysis, faster responses were indicated for the 100 ms than the 500 ms condition, but this was not a predicted effect. The presentation time effects will be discussed further in the context of the combined analysis of Experiment 2, 3, and 4 picture identification data.

# CHAPTER 4

# EXPERIMENT 3

Previous studies have shown that short-term priming effects are bigger than long-term priming effects, and there seem to be different factors that affect each one (Stankiewicz, et al., 1998). It may be the case that the influence of top-down processes varies for short-term and long-term priming. Experiment 3 tested behaviorally whether top-down processing affects short-term repetition priming (Experiment 4 examined long-term priming). Within each trial, participants were primed with a picture as they performed either an n-back task or a number repetition task. Both secondary tasks required speaking numbers aloud. This was meant to produce a bottleneck effect during which participants would be prevented from covertly naming the pictures during the first phase of the experiment. That is, the phonological selection of each number excluded the possibility of simultaneously retrieving the names of the pictures (see Ferreira & Pashler, 2002). At the end of the trial, they were presented either with the same or a different picture, and they had to name it.  We expected less priming when the n-back task was performed than when the control task was performed.

## 4.1 Methods

*Participants*

Forty-eight students from the University of Texas at El Paso and the Universidad Autónoma de Ciudad Juárez participated for course credit. There were 28 women and 20 men and their mean age was 22 years. Eight additional participants completed the protocol but were excluded and replaced. Seven participants were replaced because they reported seeing fewer than 3 of the pictures presented for one of the conditions (usually for the n-back 100 ms condition),

and one failed to perform the n-back task correctly. Participants were native speakers of either English or Spanish.

*Apparatus*

The present experiment used the same equipment in Experiment 1, but it also required a high-impedance microphone for recording vocal response times.

*Design*

Experiment 3 had a 2 (secondary task) X 2 (presentation time) X 2 (picture status) repeated-measures design. For the secondary task condition, participants either performed an n-back task or a number repetition task (the same tasks from the previous experiments). The time pictures were presented was either 100 ms or 500 ms. The 2 pictures presented on each trial were either the same or different. The 'different' condition trials were used as controls. Response times and error rates in identifying the 1st picture were recorded. Response times to name the 2nd picture were used to measure short-term priming.

*Materials*

For Experiment 3, 120 digitized pictures were used. From these, 40 pictures were used for the same condition and 80 were used for the different condition. There were twice as many pictures for the different condition because two different pictures are needed to make each trial. Pictures were counterbalanced across the different conditions. Also 80 auditory strings of numbers (from 1 to 5) were used for the n-back and number repetition tasks.

*Procedure*

Participants had to identify pictures as they simultaneously performed an n-back or a number repetition task. At the end of each trial, a second picture was presented and participants had to name it. The experimental trials were blocked by the secondary task condition. For the n-

back block, 5 practice trials were given in which the prime picture was presented for 500 ms, 3 trials in which the first and the second picture were the same and 2 trials in which both pictures were different. The 40 experimental trials followed. For the number-repetition block, 3 practice trials were given with the prime picture presented for 500 ms, 1 with the same and 2 with different prime and test pictures. In a second block of 40 trials, participants had to perform all the trials in which they had to do the number repetition task. Within each secondary task block, trials were blocked by presentation time (100 or 500 ms). Participants were warned of the speed of presentation before each change. Orders of the secondary task and presentation time blocks were counterbalanced across participants. Trials for the 'same' (i.e., same picture is presented across the trial) and 'different' (i.e., two different pictures are presented across the trial) conditions were mixed randomly within each block.

As illustrated in Figure 4, trial structure and timing were the same as in Experiment 2 up through presentation of the last digit of the secondary task, including variation of when the prime picture appeared. After the $7^{th}$ digit was presented, 4.7 sec on average passed before the second picture appeared. The purpose for this was to avoid the possibility that the vocal responses for the alternative tasks would interfere with picture naming. After the final n-back task or number repetition response was given, at least 2 sec passed before the $2^{nd}$ picture appeared and stayed on the screen until they named it. This picture was either the same picture as the picture presented previously within the trial or a different one. Participants had to name this picture as quickly as possible. The lag from the offset of the prime picture to the onset of the target varied from 6 to 9 seconds depending on when the prime picture was presented.

## 4.2 Results

*Error Rates in Recognition of Prime Picture*

Responses were coded as errors when participants pressed the 'no' button indicating that they were not able to see the picture or when they failed to press any of the two buttons. Error rates are presented in Table 2. A 2 (presentation time) X 2 (secondary task at encoding) ANOVA was performed on picture identification error rates. There was a main effect of presentation time, $F(1, 47) = 37.381$, $MSE = 4.566$, $p < .001$, with more errors when pictures were presented for 100 ms than when they were presented for 500 ms. This was true for the n-back task and for the number-repetition task, [$t(47) = 5.184$, $p < .001$; $t(47) = 5.338$, $p < .001$]. There was also a main effect of secondary task at encoding, $F(1, 47) = 11.121$, $MSE = 2.731$, $p = .002$, with more errors when participants performed the n-back task than when they performed the number repetition task. This effect was significant for both the 100 ms and 500 ms conditions, [$t(47) = 2.680$, $p = .010$; $t(47) = 2.611$, $p = .012$]. The interaction between presentation time and secondary task was not significant, $F(1, 47) = .160$, $MSE = 1.627$, $p = .691$.

*Response Times in Recognition of Prime Picture*

Only correctly identified pictures, where participants reported seeing the picture by pressing the 'yes' button were used. Responses that lasted less than 200 ms, more than 3000 ms, or three standard deviations away from the mean of the condition were removed. Response times are given in Table 2. A 2 (presentation time) X 2 (secondary task at encoding) ANOVA was performed on picture identification response times. The effect of presentation time was almost significant, $F(1, 47) = 3.495$, $MSE = 47885$, $p = .068$, in the direction of shorter response times for the 100 ms in contrast with the 500 ms condition. The effect reached significance for the number repetition condition but not for the n-back condition [$t(47) = 2.073$, $p = .044$; $t(47) =$

1.182, *p* = .243]. There was a significant main effect of secondary task at encoding, $F(1, 47) = 14.075$, $MSE = 55476$, $p < .001$, with longer response times for the n-back than for the number repetition task. This difference was significant for both the 100 ms and 500 ms conditions, [$t(47) = 4.175$, $p < .001$; $t(47) = 2.482$, $p = .017$]. The interaction between secondary task and presentation time was not significant, $F(1, 47) = .005$, $MSE = 29201$, $p = .944$.

*Response Times for Naming Test Pictures*

The naming response times from the test task were analyzed. Response times were analyzed using only trials in which the 1$^{st}$ picture was identified (when participants pressed the 'yes' button) and the 2$^{nd}$ picture was correctly named. As in the previous experiments, response times less than 200 ms, more than 3000 ms, or more than three standard deviations away from the mean of the condition were removed. Naming response times and priming scores are given in Table 3.

A 2 (picture status) X 2 (secondary task at encoding) X 2 (presentation time) ANOVA was performed on picture naming response times. A significant main effect of picture status showed that there was facilitation when the two pictures were the same relative to when they were different, $F(1, 47) = 97.076$, $MSE = 26378$, $p < .001$. Response times were significantly longer for the n-back than for the number repetition condition, $F(1, 47) = 25.635$, $MSE = 51702$, $p < .001$. Most importantly, there was a significant interaction between picture status and secondary task at encoding, $F(1, 47) = 57.256$, $MSE = 11860$, $p < .001$, indicating weaker facilitation for the n-back than for the number repetition condition. When the pictures were different, response times for the n-back and the number repetition conditions did not differ, $t(47) = 1.264$, $p = .213$. However when pictures were the same, response times were longer for the n-back condition than for the number repetition condition, $t(47) = 8.059$, $p < .001$. Response

times did not differ between the 100 and 500 ms conditions, $F(1, 47) = .730$, $MSE = 19357$, $p = .397$. The two-way-interactions between presentation time and picture status, and between presentation time and secondary task were not significant, [$F(1, 47) = .185$, $MSE = 10101$, $p = .669$; $F(1, 47) = 2.267$, $MSE = 15879$, $p = .139$]. The three-way interaction also was not significant, $F(1, 47) = .003$, $MSE = 9751$, $p = .959$.

### 4.3 Discussion

For prime picture identification, as in Experiment 2 there were significantly more errors for the n-back than for the number repetition condition. There were also significantly slower response times for the n-back condition than for the number repetition condition. Recall that for Experiment 2, response times were larger numerically for the n-back than for the number repetition condition but did not reach statistical significance. For the response times, the effect of presentation time approached significance showing shorter response times for the 100 ms than for the 500 ms condition only for the number repetition task. As in Experiment 2, the interaction between response times and secondary tasks was not significant, suggesting that the n-back task affected the two presentation times similarly.

Within response times for test pictures, as expected there was priming for the ‘same’ condition relative to the ‘different’ condition. However, the most important finding was that there was less priming for the n-back condition than for the number repetition condition. This result confirms that top-down processes are involved in short-term priming effects in picture identification. This was consistent with a previous study in which participants were presented simultaneously with two pictures but were instructed to attend only to one (Stankiewicz et al., 1998). Priming effects were reduced for the unattended pictures suggesting that attention plays an important role in short-term priming. Thus, the study from Stankiewicz et al (1998) and the

present study showed very similar results using two different methods to interrupt short-term priming. This supports the idea that top-down and attentional processes are related, and that attention is important in short-term priming.

# CHAPTER 5

# EXPERIMENT 4

Experiment 4 tested behaviorally whether performing a top-down processes task reduces long-term priming effects. This is different from Experiment 3, which tested whether top-down processing affects short-term repetition priming. The experiment was divided in two stages. In the first stage, participants had to identify a group of pictures by pressing a button, using a procedure similar to that of Experiment 2. During the second stage, participants named the pictures presented during the first stage along with new pictures not previously presented.

In the first stage, participants had to identify pictures while simultaneously performing either an n-back task a number repetition task. Similarly to Experiment 3, both secondary tasks required speaking numbers aloud to prevent from covertly naming the pictures during the first phase of the experiment. We predicted that the results from the first stage would replicate the results from Experiment 2. For this stage, the response times were recorded from the onset of each picture to the moment they were named. The response times from the first stage were analyzed to see whether participants took longer to identify a picture when they were doing an n-back task than when they were doing a number repetition task.

The response times from the second stage were used to measure and compare long-term priming effects across conditions (priming in the secondary task at encoding condition relative to new items). We predicted that the priming effects in picture naming would be reduced for the trials in which an n-back task was performed. More specifically, the allocation of top-down resources to the n-back task would reduce the long-term priming effects in the object identification process of picture naming. Previous evidence showed that the ventrolateral PFC is associated with the direct intention to remember visual information (e.g., Henson, Shallie, &

Dolan, 1999). That is, this area was active when participants were instructed to remember visual displays, but not when they were only instructed to look at them. Thus, it is possible that dividing attention with the n-back task may affect the PFC and as a consequence disrupt the long-term priming effects.

## 5.1 Methods

*Participants*

Sixty-four students were recruited from the University of Texas at El Paso and the Universidad Autónoma de Ciudad Juárez. There were 31 women and 33 men. The mean age was 21.4 years. Participants were native speakers of English or Spanish. Participants received course credit for participating. There were 16 additional participants who were excluded and replaced. The cause for 10 replacements was that participants reported seeing fewer than 3 pictures for one or more conditions (mainly for 50 and 100 ms test conditions). Four participants were replaced because they showed a strange response pattern when reporting whether they were able to see the pictures (e.g., reporting that they saw none or all of the pictures) and there was some concern that they did not follow the instructions. Two participants were replaced because the computer crashed.

*Apparatus*

The present experiment used the same equipment used for Experiment 3.

*Design*

Experiment 4 had a 3 (presentation time at encoding) X 2 (secondary task at encoding) repeated-measures design with a new-item control condition (also within-subjects). The presentation time of each picture at encoding was either 50, 100, or 500 ms. The secondary task at encoding was either performing an n-back or a number repetition task. The n-back and number

repetition tasks were the same as the ones used for Experiment 1. Response times and error rates from the encoding phase (i.e., first stage) were recorded. Response times from the test phase (i.e., second stage) were used to calculate priming effects.

*Materials*

For the present experiment 160 digitized pairs of pictures were used. Items were divided randomly into 8 sets of 20. For each experiment, 6 sets were used for the repeated conditions, and 2 sets were used as new items (control condition). For the secondary tasks, 120 strings of seven numbers (from 1 to 5) from Experiment 1 were used.

*Procedure*

The experiment was divided into two parts, the encoding phase and the test phase. During the encoding phase, participants tried to identify pictures while either performing an n-back task or a number repetition task. In this phase, the pictures were presented for 50, 100, or 500 ms, and participants had to identify each picture by pressing a button. The encoding phase was blocked by the secondary task and by the presentation time conditions. In one block of trials, participants had to perform 5 practice and 60 experimental with a concurrent n-back task. In a second block of trials, participants had to perform 3 practice and 60 experimental trials with a concurrent number repetition task. Practice trials had 500 ms presentation times, and the sets of experimental trials were subdivided into three blocks of 20 trials, one for each presentation time (i.e., 50, 100, and 500 ms). Participants were warned of the speed of presentation before each change. The orders of the concurrent task and presentation time blocks were counterbalanced across participants.

The procedure within each encoding-phase trial for Experiment 4, as illustrated in Figure 5 was very similar to that of Experiment 2 (see Figure 3). However, please note that in the

present experiment participants did not name the pictures during the first phase of the experiment, they only named them during the second part. This is different from Experiment 2 in which participants had to name each picture at the end of every trial.

During the test phase, participants had to name 160 pictures, 120 that were presented during encoding, and 40 new pictures that were not presented during the encoding phase. At the beginning of this phase, participants performed 5 practice picture-naming trials to get familiar with the microphone and with the naming task in general. Repeated and new pictures were randomly intermixed. Pictures were presented one at a time with no mask. Participants had to name each picture aloud as quickly and accurately as possible and there was no secondary task. Pictures remained on the screen until a vocal response triggered the voice relay. Vocal response times were measured, and the experimenter noted any unexpected responses.

## 5.2 Results

### *Error Rates in Object Recognition*

Responses were coded as errors when participants pressed the 'no' button indicating that they were not able to see the picture or when they failed to press any of the buttons. Error rates are given in Table 4. A 3 (presentation time) X 2 (secondary task) ANOVA was performed on error rates. There was a main effect of presentation time, $F(2, 126) = 368.19$, $MSE = 6.621$, $p < .001$. Planned comparisons showed more errors for the 50 ms condition than for the 100 or 500 ms conditions [$F(1, 63) = 301.209$, $MSE = 6.537$, $p < .001$; $F(1, 63) = 505.053$, $MSE = 9.393$, $p < .001$] . Also there were more errors for the 100 ms condition than for the 500 ms condition, $F(1, 63) = 152.637$, $MSE = 3.933$, $p < .001$. There was a main effect of secondary task, $F(1, 63) = 23.579$, $MSE = 7.238$, $p < .001$. That is, there were significantly more errors for the n-back condition than for the control condition. This difference was significant for the 50, 100, and 500

ms conditions, [$t(63) = 2.760$, $p = .008$; $t(63) = 4.564$, $p < .001$; $t(63) = 3.637$, $p = .001$]. The interaction was significant, $F(2, 126) = 3.731$, $MSE = 4.124$, $p = .027$. The effect of secondary task was bigger for the 100 ms condition than for the 500 ms condition, $F(1, 63) = 11.930$, $MSE = 5.071$, $p < .001$. However, the effect of secondary task did not differ for the 50 ms and 100 ms ($F(1, 63) = .899$, $MSE = 10.047$, $p = .347$) or for the 50 ms and 500 ms conditions ($F(1, 63) = 2.367$, $MSE = 9.623$, $p = .129$).

*Response Times in Object Recognition*

Only correctly identified pictures, where participants reported seeing the picture by pressing the 'yes' button were used. Responses that lasted less than 200 ms, more than 3000 ms, or three standard deviations away from the mean of the condition were removed. Response times in object recognition are in Table 4. One participant was excluded from the analysis because all of his response times were larger than 3000 ms.

A 3 (presentation time) X 2 (secondary task) ANOVA was performed on identification response times in the encoding phase. The main effect of presentation time was not significant, $F(2, 124) = .938$, $MSE = 22346$, $p = .394$. However, there was a main effect of secondary task showing that participants were slower to respond when they performed the n-back task than when they performed the number repetition task, $F(1, 62) = 8.480$, $MSE = 63857$, $p = .005$. This difference was significant for the 50, 100, and 500 ms conditions, [$t(62) = 2.374$, $p = .021$; $t(62) = 2.315$, $p = .024$; $t(62) = 2.682$, $p = .009$]. The interaction between presentation time and secondary task was not significant, $F(2, 124) = .479$, $MSE = 12826$, $p = .620$.

*Response Times in Picture Naming*

Response times in the test phase were analyzed using only pictures that were both identified in the encoding phase (when participants pressed the 'yes' button) and named correctly

in the test phase. Responses that lasted less than 200 ms, or more than 3000 ms, or were three standard deviations below or above their corresponding mean were removed. The naming time from the repeated condition was subtracted from the new condition to calculate priming scores. Picture naming response times and priming scores are given in Table 5. Priming was not statistically reliable in any cell (*ps* > .10). Dependent sample t-tests were performed between the raw scores from the repeated (pictures presented at encoding) and new-item control condition to test for significant facilitation or interference effects. There were no significant differences for the n-back or the number repetition conditions at 50, 100, or 500 ms. Neither the average across the different time presentations for the n-back condition nor the average for the number repetition condition was significantly different from the new-item control condition, [$t(63) = .831$, $p = .409$; $t(63) = 1.512$, $p = .135$]. These suggest that there were no priming effects for the test or for the control conditions.

Using these priming scores a 3 (presentation time) X 2 (secondary task at encoding) ANOVA was performed. There was a main effect of secondary task, $F(1, 63) = 5.951$, $MSE = 12638$, $p = .018$, with the n-back condition showing lower priming scores than the number repetition condition. There was no main effect of presentation time, $F(2, 126) = 2.218$, $MSE = 13056$, $p = .113$, and the interaction was not significant, $F(2, 126) = 1.120$, $MSE = 15344$, $p = .330$.

## 5.3 Discussion

In terms of error rates and response times in object recognition, the results from Experiment 2 and 3 were replicated. As expected, there were slower responses and larger error rates for the n-back condition than for the number repetition condition. Just like in Experiments 2 and 3, the interaction between time presentation and secondary task was not significant for

response times. However, in contrast with Experiments 2 and 3, there was a significant interaction in terms of error rate showing that the effect of the n-back task was larger for the 100 ms than for the 500 ms presentation time.

As expected, there was a significant overall difference in priming scores between the n-back and the number repetition conditions. That is, the n-back scores tended towards negative priming while the number repetition scores showed positive priming effects. However these results are inconclusive because these scores do not represent significant priming effects (i.e., they are not significantly different from zero). This suggests that our assumption that performing the performing the secondary task would prevent naming was correct. However, the finding that not even masked pictures presented for 500 ms could produce long-term priming is surprising. Contrary to what was expected, response times in picture naming showed no significant priming effects. Many neurological (e.g., Ghuman et al., 2008) and behavioral (Stankiewicz, et al., 1998) studies support the involvement of top-down processes in long-term priming. These findings show that it is very likely that the concurrent performance of the n-back task and a picture identification task will reduce long-term picture priming. Thus, further research is needed in which the possibilities to produce long-term priming are increased (e.g., presenting pictures for longer times and without a mask) to test effects of disrupting top-down processes (by concurrent performance of the n-back task) during encoding.

## 5.4 Combined Analysis

A combined analysis was performed on the object identification scores from Experiment 1, 2, and 3. There were 160 participants across the 3 experiments. Only the 100 and 500 ms conditions were used for this combined analysis given that Experiment 3 did not have the 50 ms condition. The purpose of this analysis was to use the combined power of all three experiments

to test the key hypothesis about effects of concurrent task and presentation time on object recognition.

*Error Rates in Object Recognition*

Error rates are presented in Table 6. A 2 (presentation time) X 2 (secondary task) ANOVA showed that there were more errors for the 100 ms condition than for the 500 ms condition, $F(1, 159) = 170.937$, $MSE = 120.294$, $p < .001$. This difference was significant for the n-back and the number repetition conditions, [$t(159) = 11.061$, $p < .001$; $t(159) = 10.913$, $p < .001$]. Also, there were more errors for the n-back than for the number repetition condition, $F(1, 159) = 56.457$, $MSE = 82.037$, $p < .001$. The interaction between presentation time and secondary task was significant, $F(1, 159) = 8.66$, $MSE = 53.192$, $p = .004$. The n-back task hurt performance more in the 100 ms condition than in the 500 ms condition.

*Response Times in Object Recognition*

Response times are shown in Table 6. A 2 (presentation time) X 2 (secondary task) ANOVA was performed on data from 159 participants. (The same participant that was excluded from Experiment 4 was again excluded). Response times were faster for the 100 ms condition than for the 500 ms condition, $F(1, 158) = 8.943$, $MSE = 20815$, $p = .003$. The effect was significant for both the n-back and the number repetition condition [$t(158) = 2.112$, $p = .036$; $t(158) = 2.640$, $p = .009$]. Also, participants were slower for the n-back condition than for the number repetition condition, $F(1, 158) = 23.073$, $MSE = 32626$, $p < .001$. The interaction between presentation time and secondary task was not significant, $F(1, 158) = .412$, $MSE = 11875$, $p = .522$.

Overall, the combined results showed that the n-back task affects object recognition by increasing error rate and response times. The interaction between presentation time and

secondary task in terms of error rates showed that the n-back task has a larger effect on shorter presentation times than the control condition. Unexpectedly, participants were faster for the 100 than for the 500 ms condition. One possible explanation of this finding is that participants continue to scan the stimulus until it disappears to increase the chances of item recognition. As a result, they wait until after the item disappears from the screen to initiate the button press, thus taking them longer to respond in the 500 than in the 100 ms condition. Another possibility is that the items that would take longer to identify are more likely to be identification failures in the shorter presentation time conditions and excluded from the response time analysis, leaving only the easier items which are identified faster for inclusion in the response time analysis.

# CHAPTER 6

# GENERAL DISCUSSION

In this study, I have considered the influence of top-down processes in different visual abilities. Four experiments tested the effects of an n-back task performed simultaneously with different visual tasks. It was assumed that performance of the n-back task would use top-down resources. Thus, if top-down processes were involved in any of the different visual tasks, then the n-back task would negatively affect visual processing. Specifically, Experiment 1 tested the impact of an n-back task in a change detection task, and Experiment 2 tested whether the concurrent performance of an n-back task affects object identification. Experiments 3 and 4 tested whether the performance of an n-back task during picture encoding reduces short- and long-term priming respectively.

In summary, it was found that the n-back task affected the change detection and object recognition tasks by increasing error rates and response times. Also, the n-back task reduced facilitation effects in a short-term priming task. In terms of long-term priming, although the n-back condition did show smaller priming effects than the control condition, such difference was inconclusive given that neither the n-back nor the control condition showed significant priming effects relative to new items. Thus, taken as a whole, the results indicate that top-down processes are involved in change detection, object recognition and short-term priming and suggest that they may also be involved in long-term priming.

## 6.1 The Role of Attention in Change Detection

Detecting a change is easier when there is a cue to where the change will occur (e.g., motion). Change is difficult to detect in a flickering task like the one used in Experiment 1 precisely because there are no such cues available (Rensink, 1997). A mask between the

flickering images disrupts sensory memory and the sensation of motion that allows us to perceive movement in movies. Thus, within such tasks, attention needs to be directed serially through the different areas of the stimulus to detect a change.

Working memory is important in such tasks because the information from one visual item needs to be compared with the information of a second item after the second item is no longer in view and has decayed from sensory memory. Previous studies suggest that attended items are more likely to transfer from sensory memory to visual working memory (e.g., Schmidt et al., 2002). However, change detection studies suggested that sustained attention is necessary to maintain visual information in working memory rather than just to transfer it into working memory (Rensink, 2002). For example, if attention was sufficient to transfer a stable visual representation of a complex image to working memory within a flickering task, then it would be easier both to detect changes and to determine that no change occurred. However, the long response times to detect changes within a flickering task suggest that the search is done serially, thus supporting the view that attention is needed both to bind the items held in visual short-term memory to locations and to maintain the binding (Wheeler, & Treisman, 2002). Pessoa, and Ungerleider (2004) showed overlapping activity in areas involving the PFC and PC when a change was correctly reported and when a false alarm was reported in a visual working memory task.

The findings of Experiment 1 showing more errors and longer response times when a flickering task was presented concurrently with an n-back task can be interpreted according to Rensink's view. That is, the simultaneous performance of the n-back task reduced attentional resources available for the flickering task, thus making it even more difficult to maintain in working memory the two different versions of an image. It also made more difficult to direct

attention to the areas where changes may occur. Overall, Experiment 1 confirmed the central role of attention in change detection tasks.

## 6.2 Object Identification

The present behavioral findings, in agreement with previous neurological evidence support the involvement of top-down processing in object identification (Experiments 2, 3, and 4). Specifically, the disruption of top-down processes reduced speed and accuracy in object identification. There are at least two different possible explanations accounting for these findings. One explanation claims that top-down influences are only in terms of attention. The other possible explanation claims top-down influences are in terms of attention but also in terms of perception. These two explanations are evaluated below in terms of their ability to explain the object recognition results of Experiments 2, 3, and 4.

The error pattern in the object identification task (Experiment 2) was also of interest. With very short masked presentation times (50 or 100 ms), participants sometimes gave answers that were perceptually similar to what the actual object was in terms of general shape (low-frequency aspects but not details) (e.g., *cone* for skirt), and although the number of instances was insufficient for a conclusive determination, these errors occurred numerically more often in the n-back condition. Participants also sometimes were able to detect parts of the object but were not able to determine what the actual object was. These types of errors did not occur when pictures were presented in full view for the picture naming tasks in Experiments 3 or 4.

### *The Role of Attention in Object Identification*

It is possible that such disruption affected neurological activities associated with attention such as: (1) increasing firing rates of cells responding to the attended object (e.g., Spitzer, et al., 1988); (2) screening out irrelevant information (e.g., Raynolds, et al., 1999); (3) increasing

baseline activity before the to-be attended object is presented (e.g., Luck, et al., 1997); and (4) and enhancing visual contrast (see Kastner & Ungerleider, 2000). Thus a reduction in attention can reduce the efficiency of sensory areas making the process of object recognition slower and more prone to errors.

Another factor that could have affected object recognition is a disruption of normal saccade processes. As mentioned earlier, performance of an n-back task reduces saccade control (Mitchell, et al., 2002). It is possible that participants were slower in directing their saccades toward the pictures, which would affect both error rates and response times. There is a latency of 150 to 175 ms to initiate a saccade, and it takes another 30-50 ms to make the saccade itself, depending on the visual angle to be traversed (Rayner, 1998). Recall that the mask that preceded the stimulus in Experiments 2, 3, and 4 was presented for 250 ms. If participants were not looking directly at the center of the screen, the mask would cue them to initiate a saccade to that area. Under full attention, 250 ms ought to be enough time to make a saccade on time to the center of the screen before the stimulus appears. However their attention was occupied by the n-back task, which disrupts saccade processing (Mitchell, et al., 2002). In terms of error rates, it is possible that participants were not able to make a saccade in time to adequately scan the picture. In terms of response times, it is possible that the saccade disruption caused by the n-back task made participants to scan the picture at a later time in contrast with the control, thus taking longer to recognize the pictures. Some support for this explanation was seen in the reports by several participants that on some n-back trials for short presentation times (50 or 100 ms), they did not believe that a picture had even been presented. This phenomenon would make sense if the saccade reached the target location after the picture had offset and they only saw the second mask.

The unusual perceptual errors (e.g., perceiving a monkey as a man) that occurred in Experiment 1 could be caused by decreased attention. Attention reduction can increase the difficulty of screening out irrelevant information and/or the difficulty of enhancing visual contrast (e.g., Raynolds, et al., 1999; Kastner & Ungerleider, 2000). It can also fail to increase firing rates responding to the attended object before and during the presentation of the object (Sùper, 2005; Kastner & Ungerleider, 2000). These factors can create a situation in which participants do not detect details (high-frequency characteristics) of the objects but only the overall shape of the objects (low-frequency characteristics), thereby making object recognition more difficult. Within the attentional view, these types of errors suggest that attention may not carry visual information, but it is essential to make visual information more accessible.

*The Role of Top-Down Perceptual Processes in Object Recognition*

A different hypothesis suggests that the influence of top-down processes in object recognition is in terms of visual perception. Previous research suggests that top-down processes in the PFC send a visual sketch of a perceived object to the occipitotemporal areas, before low-level visual areas finish processing the object (Bar, 2003, 2006). The information sent from high-level areas to occipitotemporal regions seems to reduce the time it takes to recognize the perceived object. This hypothesis can also account for the present findings. For example, it is possible that the PFC was not able to send a sketch of each perceived object, thus increasing the time it took to identify the object. However, Bar's model does not predict that disruption of the PFC would produce more object identification errors. The reason is that in his model, the bottom-up processes are sufficient to identify the object, and the top-down influences only serve to facilitate or speed the identification processes. Thus, while the present findings support Bar's model by showing that object identification is slowed when top-down processes are disrupted,

the model is not supported in that more errors were found when top-down processes were disrupted.

Nevertheless, Bar's model can account for some unusual errors (e.g., errors in which the name of an object similar in shape to the actual object was given) made during the 50 ms condition. That is, given that without top-down processes object recognition is slower, it is possible that there was not enough time to fully identify the object. Specifically, the low-level visual areas were only able to capture the overall shape of the objects, and without the aid of top-down processes this information was not enough to correctly identify the actual object.

The present findings are more in agreement with the possibility that top-down processes influence object recognition in terms of attention. However, these findings are not able to rule out the possibility that the PFC influences object recognition also in terms of perception. Given that the n-back task was used to disrupt top-down processes, it was not possible to only disrupt the PFC. Thus, the results from Experiment 2, 3, and 4 can be accounted by a disruption of brain areas associated with attentional processes (e.g., PFC, PC, and premotor cortex), and by disrupting the area associated with top-down perceptual processes (i.e., PFC). Further research in which only the PFC is disrupted would permit to test whether the PFC carries perceptual information or whether its role is just in terms of attention.

### 6.3 The Role of Perception and Attention in Working Memory

As mentioned before, Experiment 1 confirmed the central role of attention in working memory. Experiment 2, 3, and 4 confirmed that attention affects object identification. Thus, it becomes relevant to explain a possible relation between attention, perception, and working memory. There are two main questions about working memory. The first is where the information is stored, and the second is how it is maintained. In a previous section it was

presented evidence showing that attention is needed to prevent loss of information from working memory. In terms of where this information is stored, there is evidence suggesting that such information is stored within higher-level perceptual areas (Jonides, Lacey, & Nee, 2005). That is, information about object characteristics is stored within the temporal areas and information about the location of the object is stored in parietal areas. For example, cells in temporal cortex are active after the first picture but before the second picture is presented in a delayed match-to-sample task (Miller, & Desimone, 1994). Also, human patients with damage in parietal cortex show deficits in spatial working memory (e.g., Hanley, Young, & Pearson, 1991). This evidence led Jonides et al. (2005) to suggest that working memory is stored within the perceptual systems and attention is necessary to maintain it. Thus, it is likely that the strong influence of attention in perceptual areas is not just to improve perceptual abilities but it is also to help maintain working memory information.

### 6.4 Top-Down Processing Involvement in Short-Term and Long-Term Priming

Concurrent performance of an object-recognition and an n-back task showed a reduction in short-term priming effects. Neuroimaging studies had shown that activity in ventral occipital areas is greatly reduced the second time nonsense objects (i.e., do not have a mental representation) were presented relative to new nonsense objects (van Turennout, Ellmore, & Martin, 2000). This finding, in relation to the findings of Experiment 3 suggests that the n-back task somehow affected occipital areas and as a consequence reduced priming effects. Based on this, it is likely that top-down processes participate in short-term priming. Experiment 4 suggested that top-down processes also have an effect in long-term memory formation. However, given the n-back and the control condition did not show significant priming effects more experiments need to be performed to confirm this finding.

It is unlikely that covert naming of the pictures produced the short-term priming effects. One reason to affirm this is that both secondary tasks required speaking numbers aloud. This produced a bottleneck effect preventing participants from covertly naming the pictures during the first phase of the experiment (see Ferreira & Pashler, 2002). Another reason is that there were no significant long-term priming effects in Experiment 4. Previous evidence has shown that naming pictures (even covertly) produces large long-term priming effects (Brown, Neblett, Jones, & Mitchell, 1991; Francis et al., 2008). Thus, the fact that there was no priming in Experiment 4 indicates that participants were not covertly naming the pictures in the encoding phase. It is therefore inferred that participants from Experiment 3 did not covertly name the prime pictures.

## 6.5 Future Directions

There are at least two possible lines of research to further the findings of the present study. In Experiment 1 it was suggested that changes that occurred in the marginal areas of the photos were more difficult to detect than changes that occurred in the areas of central interest. However, it is not clear from Rensink's study (1997) what is the exact difference between marginal and central interest in a complex picture (e.g., Figure 1). His method of classifying pictures into the two categories was to have participants view the two alternate versions of each picture and indicate whether the change was in a central or marginal region. This method may not be adequate as a preliminary analysis of the photos used for Experiment 1 showed low agreement in terms of which photos showed a change in areas of central or marginal interest. It is possible that many different characteristics within complex images can be considered to be of central interest (e.g., a person, its aesthetic composition, etc.). A possible solution to this problem is to perform an experiment similar to Experiment 1 but using eye-tracking methodology. The eye-tracking apparatus would allow measurement of which areas are fixated

first and for how long. It would allow for central and marginal interest areas to be defined operationally in terms of the time it takes for a participant's gaze to fixate on the region of the scene in which the change occurs. This is a more objective approach and puts centrality or marginality on a continuum rather than treating them as a dichotomy. In turn, this will permit testing whether the n-back task has a different effect on pictures with changes on central and marginal interest or those that are fixated earlier or later in viewing the scene.

As mentioned previously, with the n-back task it was not possible to disrupt only the PFC to test its direct effect in object recognition and in repetition priming. A more selective and more complete disruption of PFC can be accomplished using transcranial magnetic stimulation (TMS), in which a magnetic field pulse is passed through the area to be disrupted. It is used to simulate the effects of a focal brain lesion but the function is disrupted for only a few seconds at a time. Using TMS instead of the n-back task to disrupt specific areas such as PFC and PC will permit testing the specific functions of each of these two areas in object recognition. For example, object recognition can be tested while disrupting the ventrolateral areas of PFC, and be compared to a control in which a specific area of the brain not involved in object recognition is disrupted. This experiment could test the specific function of ventrolateral PFC in object recognition, and help to differentiate between attentional and perceptual top-down influences.

## 6.6 Conclusion

The present study showed the importance of top-down processes in attention, object recognition and short-term priming. Change detection and object recognition performance decreased when top-down processes were disrupted showing that there is a close relation between visual perception, attention, and working memory. Attention plays an important role in facilitating visual perception and in maintaining visual information in working-memory. It was

also shown that top-down processes influence short-term priming. However, future research it is still needed to fully understand the specific role of top-down processes in short-term priming. Long-term priming effects were also affected by disrupting top-down processes, although the results were inconclusive. The pattern of results across the 4 experiments indicates that in order to fully understand central cognitive processes such as attention, object recognition, working memory, short-term, and long-term priming, top-down processes cannot be ignored. The present study supports theoretical approaches to visual processing that include a role for feedback from higher-level brain areas.

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Table 1

Object Recognition Performance in Experiment 2 as a Function of Concurrent Task and Presentation Time (Standard Deviations).

| | Error Rates (%) | | Response Times (ms) | |
|---|---|---|---|---|
| Presentation Time | N-Back | Control | N-Back | Control |
| 50 ms | 60.4 | 47.9 | 460 | 478 |
| | (4.1) | (3.9) | (205) | (221) |
| 100 ms | 25.4 | 16.5 | 457 | 430 |
| | (3.5) | (2.8) | (156) | (187) |
| 500 ms | 10.4 | 3.4 | 505 | 468 |
| | (1.8) | (1.3) | (166) | (193) |

Table 2

Object Recognition Performance in Experiment 3 as a Function of Concurrent Task and Presentation Time (Standard Deviations)

| | Error Rate (%) | | Response Time (ms) | |
|---|---|---|---|---|
| Presentation Time | N-Back | Control | N-Back | Control |
| 100 ms | 18.1 | 14.0 | 778 | 688 |
| | (2.0) | (1.9) | (306) | (325) |
| 500 ms | 8.9 | 5.5 | 818 | 730 |
| | (1.3) | (0.8) | (337) | (328) |

Table 3

Response Times for Picture Naming in Experiment 3 as a Function of Concurrent Task, Match Between Prime and Target, and Prime Presentation Time (Standard Deviations)

| Prime | Same Picture RT (ms) | | Different Picture RT (ms) | | Priming (ms) | |
|---|---|---|---|---|---|---|
| Presentation | N-Back | Control | N-Back | Control | N-Back | Control |
| 100 ms | 1091 | 871 | 1175 | 1122 | 84 | 251 |
| | (251) | (241) | (285) | (264) | (175) | (182) |
| 500 ms | 1065 | 882 | 1139 | 1125 | 74 | 244 |
| | (311) | (243) | (252) | (248) | (172) | (151) |

*Note*: Priming scores were obtained by subtracting the mean of the same picture condition from the mean of the different picture condition.

Table 4

Object Recognition Performance in Experiment 4 as a Function of Concurrent Task and Presentation Time (Standard Deviations)

| | Error Rate (%) | | Response Time (ms) | |
|---|---|---|---|---|
| Presentation Time | N-Back | Control | N-Back | Control |
| 50 ms | 50.2 | 43.0 | 955 | 890 |
| | (3.9) | (3.6) | (277) | (277) |
| 100 ms | 23.8 | 13.9 | 935 | 865 |
| | (3.5) | (2.3) | (293) | (281) |
| 500 ms | 5.0 | 2.0 | 968 | 876 |
| | (1.3) | (0.8) | (334) | (339) |

Table 5

Picture Naming Response Times and Priming in Experiment 4 as a Function of Concurrent Task and Prime Presentation Time (Standard Deviations)

| Presentation Time For Prime | Response Times (ms) N-Back | Response Times (ms) Control | Priming Scores (ms) N-Back | Priming Scores (ms) Control |
|---|---|---|---|---|
| 50 ms | 1101 | 1056 | -23 | 22 |
| | (266) | (196) | (191) | (123) |
| 100 ms | 1105 | 1067 | -27 | 11 |
| | (239) | (212) | (135) | (127) |
| 500 ms | 1058 | 1056 | 20 | 21 |
| | (186) | (203) | (109) | (119) |

*Note*: Mean RT for new items was 1078 (*SD* = 179); priming scores were obtained by subtracting the mean for each repeated condition from this value.

Table 6

Object Recognition Performance in the Combined Analysis (N =160) as a Function of Concurrent Task and Presentation Time (Standard Deviations)

| | Error Rate (%) | | Response Time (ms) | |
|---|---|---|---|---|
| Presentation Time | N-Back | Control | N-Back | Control |
| 100 ms | 19.2 | 12.1 | 743 | 680 |
| | (16.5) | (11.6) | (330) | (325) |
| 500 ms | 6.1 | 2.4 | 783 | 709 |
| | (7.1) | (4.3) | (351) | (342) |

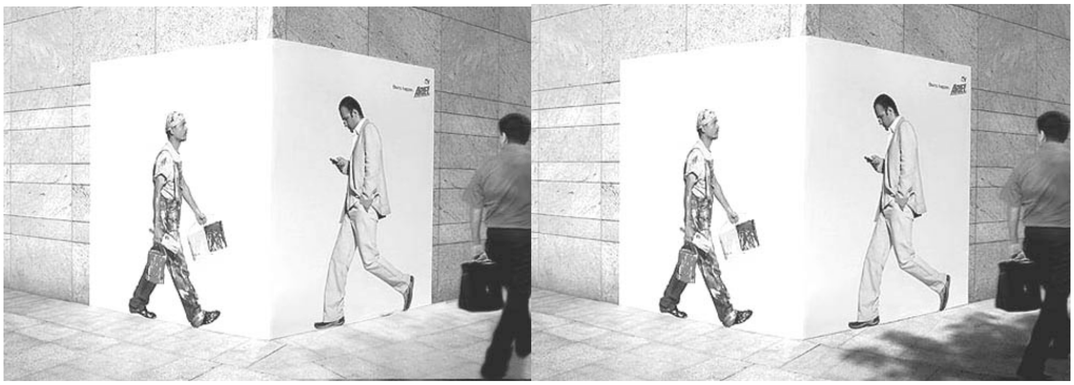

Figure 1. Example of a picture pair used in Experiment 1. The shadow in the lower right corner is what changes between these two pictures.

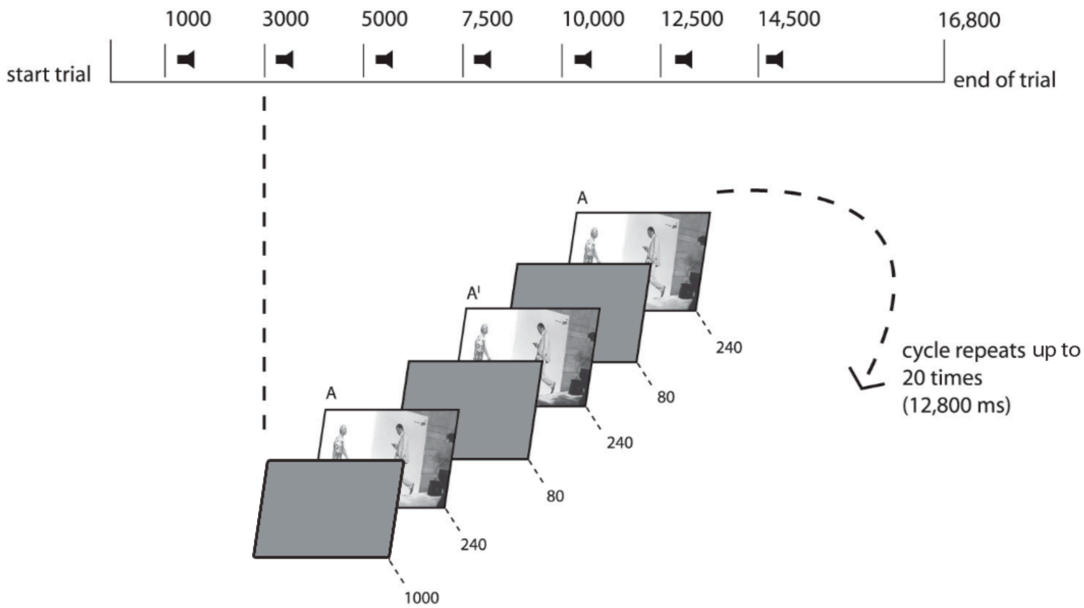


Figure 2. Trial Structure for Experiment 1. *A* and *A'* refer to alternate versions of the same picture.

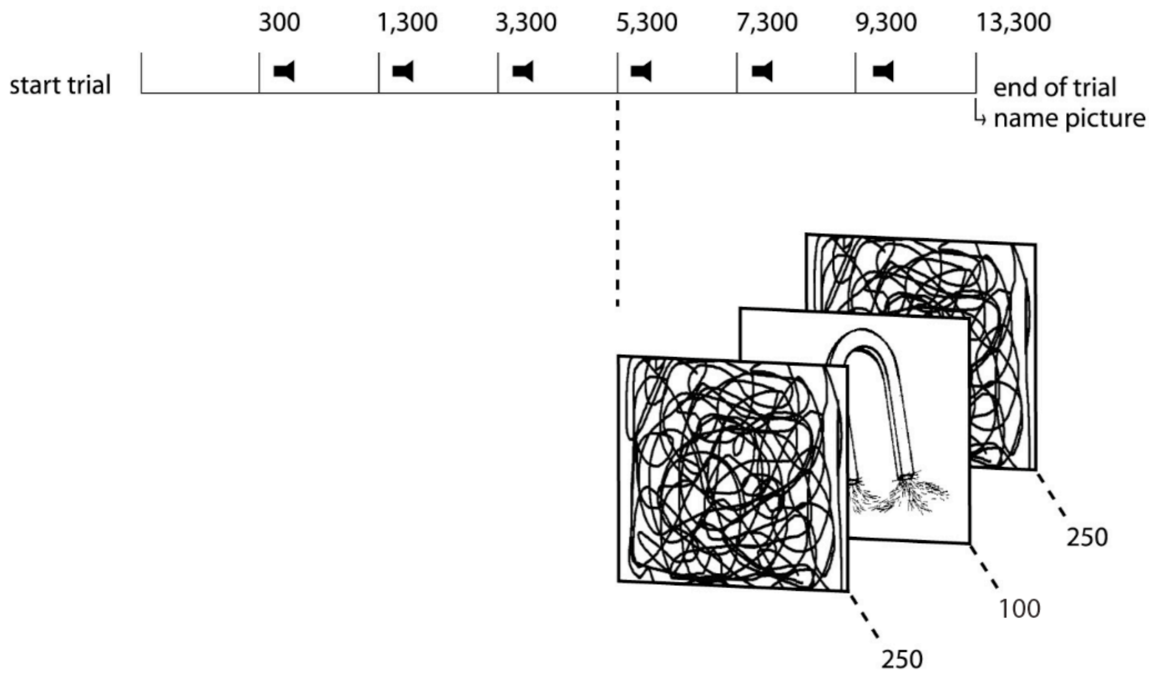


Figure 3. Trial Structure for Experiment 2. The target appeared for 50, 100, or 500 ms.

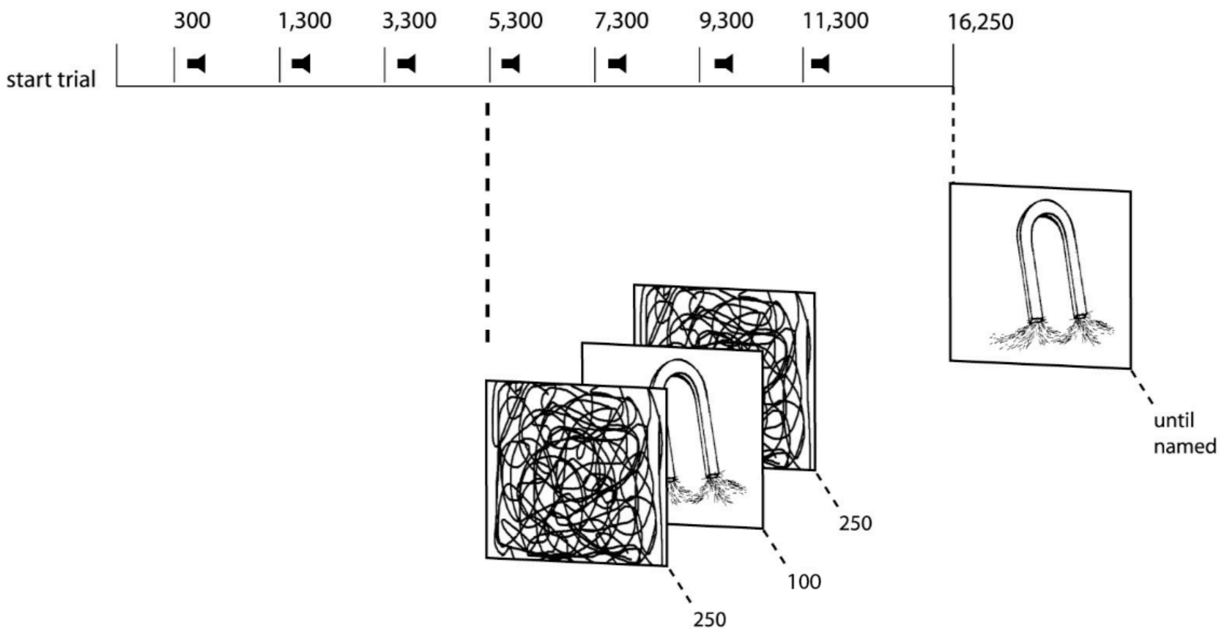


Figure 4. Trial Structure for Experiment 3. The first picture was presented for either 100 or 500 ms and was either the same or different from the final picture.

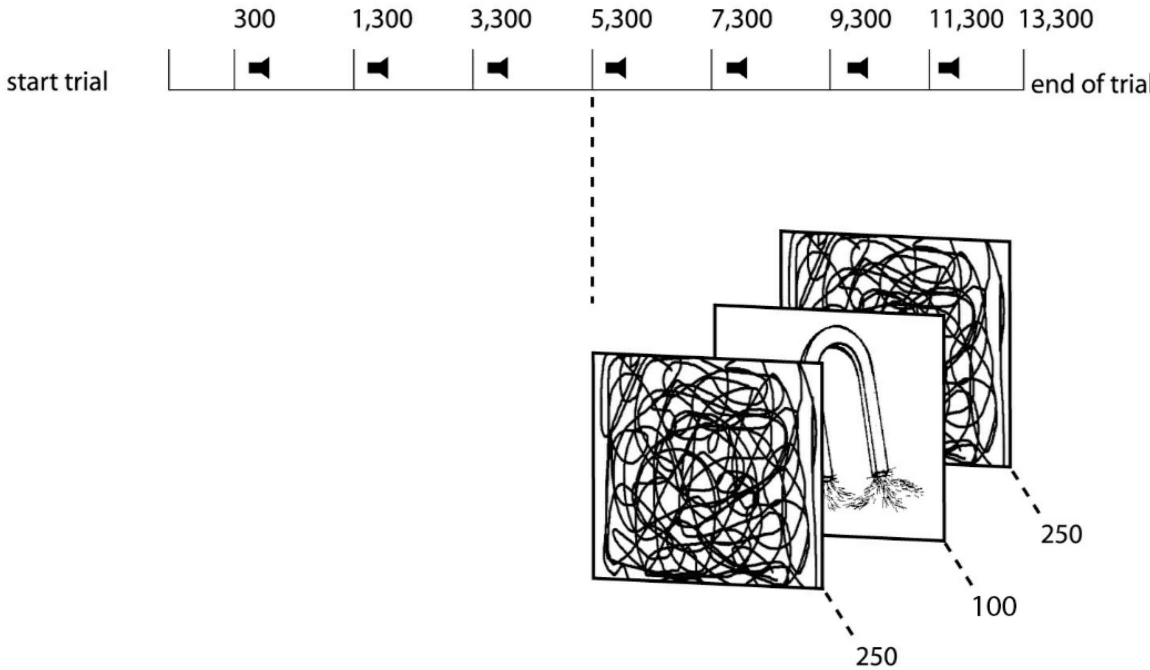


Figure 5. Trial Structure for Experiment 4 at Encoding. The target appeared for 50, 100, or 500 ms. Pictures were not named at encoding.

APPENDIX

Analyses of Arcsine Transformed Error Rates

*Experiment 1 Error Rates*

An analysis was performed for errors in which participants pressed the button but they were not able to correctly report the change, showing that there was no difference between the n-back and the number repetition conditions, $t(39) = 1.56$, $p = .126$. The item analysis also showed no difference between the n-back and the number repetition conditions, $t(39) = 1.21$, $p = .228$.

A dependent samples t-test was performed to compare time-out error rates in the n-back versus the number repetition conditions. The n-back condition showed significantly more time-out errors than the number repetition condition, $t(39) = 4.8$, $p < .001$. The item analysis also showed significantly more time-outs for the n-back than the number repetition conditions, $t(39) = 5.25$, $p < .001$.

*Experiment 2 Error Rates*

A 3 (presentation time) X 2 (secondary task) ANOVA was performed on picture identification error rates. First, there was a significant main effect of presentation time, $F(2, 94) = 230.528$, $MSE = .031$, $p < .001$, showing that error rates decreased with longer presentation time. Planned comparisons showed that there were more errors for the 50 ms condition than for the 100 and 500 ms conditions, [$F(1, 47) = 225.361$, $MSE = 0.62$, $p < .001$; $F(1, 47) = 307.470$, $MSE = .087$, $p < .001$]. Also there were more errors for the 100 ms condition than for the 500 ms condition, $F(1, 47) = 55.676$, $MSE = .036$, $p < .001$. Participants showed significantly more errors in picture identification when they performed the n-back task than when they performed the number repetition task, $F(1, 47) = 37.364$, $MSE = .023$, $p < .001$. This was true for the 50, 100, and 500 ms conditions, [$t(47) = 4.860$, $p < .001$; $t(47) = 3.599$, $p = .001$; $t(47) = 5.443$,

$p < .001$]. In contrast to the analysis of untransformed error rates, there was a significant interaction between secondary task and presentation time, $F(2, 94) = 4.586$, $MSE = 0.12$, $p = .013$. Specifically, the effect of secondary task was bigger for the 50 ms than for the 100 ms and the 500 ms conditions, [$F(1, 47) = 4.379$, $MSE = .027$, $p = .042$; $F(1, 47) = 7.298$, $MSE = .029$, $p = .010$]. However, the effect of secondary task did not differ for the 100 ms and 500 ms conditions, $F(1, 47) = .692$, $MSE = .018$, $p = .410$.

*Error Rates for Experiment 3*

A 2 (presentation time) X 2 (secondary task at encoding) ANOVA was performed on picture identification error rates. There was a main effect of presentation time, $F(1, 47) = 37.128$, $MSE = .012$, $p < .001$, with more errors when pictures were presented for 100 ms than when they were presented for 500 ms. This was true for the n-back task and for the number-repetition task, [$t(47) = 5.184$, $p < .001$; $t(47) = 5.332$, $p < .001$]. There was also a main effect of secondary task at encoding, $F(1, 47) = 11.016$, $MSE = .007$, $p = .002$, with more identification errors when participants performed the n-back task than when they performed the number repetition task. This effect was significant for both the 100 ms and 500 ms conditions, [$t(47) = 2.674$, $p = .010$; $t(47) = 2.611$, $p = .012$]. The interaction between presentation time and secondary task was not significant, $F(1, 47) = .168$, $MSE = .004$, $p = .683$.

*Experiment 4 Error Rates*

A 3 (presentation time) X 2 (secondary task) ANOVA was performed on picture identification error rates. There was a main effect of presentation time, $F(2, 126) = 327.064$, $MSE = .022$, $p < .001$. Planned comparisons showed more errors for the 50 ms condition than for the 100 or 500 ms conditions [$F(1, 63) = 274.756$, $MSE = .043$, $p < .001$; $F(1, 63) = 424.422$, $MSE = .065$, $p < .001$] . Also there were more errors for the 100 ms condition than for the 500 ms

condition, $F(1, 63) = 144.403$, $MSE = .022$, $p < .001$. There was a main effect of secondary task, $F(1, 63) = 23.393$, $MSE = .022$, $p < .001$, with significantly more errors for the n-back condition than for the control condition. This difference was significant for the 50, 100, and 500 ms conditions, [$t(63) = 2.858$, $p = .006$; $t(63) = 4.548$, $p < .001$; $t(63) = 3.636$, $p = .001$]. The interaction was significant, $F(2, 126) = 3.702$, $MSE = .013$, $p = .027$. The effect of secondary task was bigger for the 100 ms condition than for the 500 ms condition, $F(1, 63) = 12.415$, $MSE = .014$, $p < .001$. However, the effect of secondary task did not differ for the 50 ms and 100 ms ($F(1, 63) = .311$, $MSE = .032$, $p = .579$) or for the 50 ms and 500 ms conditions ($F(1, 63) = 3.218$, $MSE = .032$, $p = .078$).

# CURRICULUM VITA

Gabriela Durán was born in Juárez, Chihuahua, México. She began her higher education at El Paso Community College and later transferred to the University of Texas at El Paso to pursue a bachelor's degree. She completed her bachelor of arts degree cum laude with majors in psychology and philosophy at The University of Texas at El Paso in 2002. In 2003, she entered the M.A. program in Experimental Psychology at the University of Texas at El Paso and completed the M.A. in Experimental Psychology in 2005. In 2006, she obtained a full-time faculty position in the Department of Visual Arts at the Universidad Autónoma de Ciudad Juárez, where she currently works. In 2006, she also entered the Ph.D. Program in Psychology at the University of Texas at El Paso, within the Social, Cognitive, and Neuroscience concentration area. She completed her Ph.D. in 2009.

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