CONTEXTUAL MODULATION OF COMPETITIVE OBJECT CANDIDATES IN EARLY OBJECT RECOGNITION

by

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Elan Barenholtz, Department of Psychology, and has been approved by the members of his supervisory committee. It was submitted to the faculty of the Charles E. Schmidt College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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ABSTRACT

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Object recognition is imperfect; often incomplete processing or deprived information yield misperceptions (i.e., misidentification) of objects. While quickly rectified and typically benign, instances of such errors can produce dangerous consequences (e.g., police shootings). Through a series of experiments, this study examined the competitive process of multiple object interpretations (candidates) during the earlier stages of object recognition process using a lexical decision task paradigm. Participants encountered low-pass filtered objects that were previously demonstrated to evoke multiple responses: a highly frequented interpretation ("primary candidates") and a lesser frequented interpretation ("secondary candidates"). When objects were presented without context, no facilitative effects were observed for primary candidates. However, secondary candidates demonstrated evidence for being actively suppressed.

When primed with scenes semantically relevant to primary candidates, the suppression of the secondary candidate was eliminated while primary candidates continued to lack facilitation. However, when primed with scenes consistent with secondary candidates, secondary candidates were once again suppressed. Moreover, primary candidates were facilitated. Overall findings suggest that primary candidates may actively suppress competition from lesser candidates in the earlier stages of object recognition. This effect is strengthened when the primary candidate is challenged but removed when it is reaffirmed.

CONTEXTUAL MODULATION OF COMPETITIVE OBJECT CANDIDATES IN EARLY OBJECT RECOGNITION

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INTRODUCTION

Visual object recognition is efficient, but not perfect. Accuracy of identification is sometimes sacrificed for speed of processing and optimization of resources (Bar, 2003). People often misperceive one object as an entirely different object. For instance, one may have experienced a situation where they mistook a taxi-cab for a police car. These errors are typically benign and often quickly rectified, many times with a “double-take” or second glance. Nonetheless, misperceptions have the potential to produce lethal consequences under stressful situations requiring rapid decision-making. For instance, under heavy time constraint, military cadets were more likely to interpret a tool as a gun when primed with images of middle-eastern males, consequently leading them to “shoot” a suspect they perceived as a potential terrorist (Fleming, Bandy, & Kimble, 2010). It is reasonable to mistake a power-drill for a gun. After all, both objects share similar global properties (i.e., the shape). This then raises the question: why was one interpretation of a stimulus “picked” for object recognition over another? That is, why was the tool stimulus interpreted as a gun as opposed to what it truly was—a tool? In the case of the previous study by Fleming, Bandy, and Kimble (2010), the misperception presumably stemmed from biases associated with Middle East terrorism. Indeed, top-down biases such as ethnic stereotypes strongly influence how one perceives an object; however, what are the effects of such top-down factors on the potential object interpretations *themselves* prior to final object recognition? For example, was the interpretation of “gun” facilitated or was the interpretation of “tool” suppressed? Perhaps both effects manifest. Even more concerning, perhaps the interpretation of a tool was never entertained given the context. One approach to answer this question may lie in context driven models of object recognition. Ullman (1995) first posited the generation of multiple “guesses” or “hypotheses” of an object during the early stage of recognition. These simultaneously produced guesses are generated by bottom-up information and biased by top-down processes. Furthermore, the interaction between such top-down systems and bottom-up processing eventually produce a single coherent representation used for object recognition. Developing on this idea, Bar (2003) theorized that the hypothesis generation stage was strongly guided and created by contextual cues such as scenes. Additionally, Bar (2004) added that such guesses are refined or dismissed with incoming higher level information (e.g., high spatial frequency). It may be possible that misperceptions may be generated in this “guessing” stage. If object recognition is hindered and bottom-up inputs are halted (e.g., from a saccade away from an object in the periphery), the brain should default to the most activated object interpretation for object recognition. With such partial and generalized bottom-up information available at this early stage of information processing, the most activated interpretation should be the one most influenced by top-down processes. The cadets in the study by Fleming, Bandy, and Kimble (2010) were under a time constraint, their brain’s initial guesses were possibly biased by motivating factors such as survival, fear, and stereotypes. Without more time or information to resolve such predispositions, the recognition system perhaps chose the most top-down influenced object candidate (e.g., gun).

The purpose of the current study; however, was not to assess how objects are misidentified in rare, potentially life-threatening situations. In everyday situations, objects can appear ambiguous or unclear simply by distance. Often, objects from afar appear to be blurry and critical features necessary for accurate identification dissipate into the haze, allowing for other interpretations of the object. Such ambiguity can worsen when the object lies in our periphery and we quickly move our glance away from the object. As discussed later, Bar's (2004) model of object recognition can help to explain how such problems can be alleviated by context. Conversely, Bar's model can also help explain how such problems can be facilitated in the presence of an inappropriate context. However, before further speculating how object interpretations may be influenced by higher level processing (such as decision making), it is important to elaborate Bar's (2004) object recognition model.

(Context Based) Model of Object Recognition

Bar's (2004) model is critical to the current study—specifically, the early stages where multiple hypotheses about an object is formulated. The basis of Bar's model is "contextual frame" constructs, which are memory structures created from past experiences that include prototypical information about specific objects and their relationship in that frame (contextual frames are more traditionally referred to as schemata, e.g., Bar & Ullman, 1996). These frames serve as the basis of expectations and stereotypes for specific scenes and situations. To reiterate, Bar (2004) hypothesized that "initial guesses" about an object are created by minimally processed low level information such as low spatial frequency signals. These guesses are constrained by context and eventually eliminated or refined with forthcoming higher level information about both the object and scene alongside additional top-down processing. The cycle continues until a single guess remains and is then outputted into conscious object recognition. In more detail, Bar (2003, 2004) and colleagues (Fenske, Aminoff, Gronau, & Bar, 2006) proposed that when an object is being perceived, low-spatial frequency (LSF) signals are first processed via magnocellular pathways. The global features extracted from this set of information are used to create "initial guesses" or "candidates" about the object, which serve to limit or constrain the number of interpretations for the identification of the object and scene. Bar suggested that the LSF information of the object and scene is transmitted from the visual cortex to the prefrontal cortex and parahippocampal cortex. The prefrontal cortex activates guesses about the identity of the object. Recent studies have suggested that prediction about object identities specifically originate in orbitofrontal cortex (e.g., Bar et al., 2006). Simultaneously, the parahippocampal cortex creates guesses based on experientially driven contextual frames. The information from both the orbitofrontal cortex and the parahippocampal cortex are then sent to the inferior temporal cortex. The inferior temporal cortex sorts through the information and prioritizes the guesses. Bidirectional processing continues as the information is constantly refined as higher spatial frequency information slowly filters through (Bar, 2004, see Figure 1 for schematic representation of model). Bar's model demonstrates a coactivated top-down and bottom-up mechanism for object recognition (for a more comprehensive review of the model, see O'Callaghan et al., 2017).

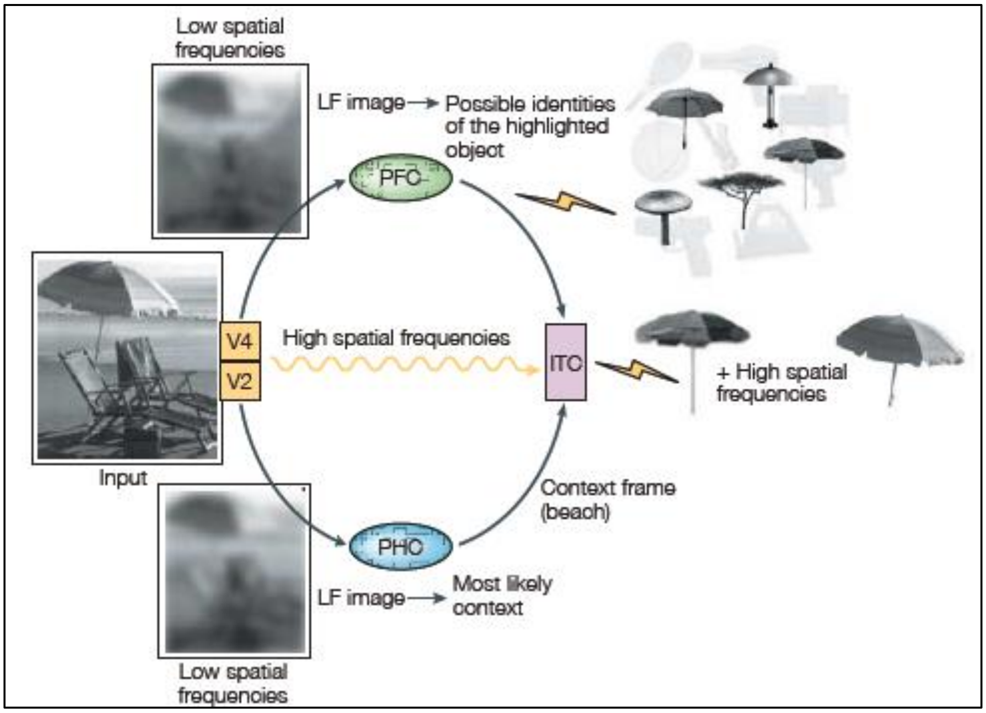

Figure 1. Bar's (2003, 2004) model of contextual facilitation. Bar proposed that the object recognition process first takes in low spatial frequency information about an object and its scene. This information is sorted and simultaneously processed in the prefrontal cortex and parahippocampal cortex. The information from the prefrontal cortex and parahippocampal cortex is then processed in the inferior temporal cortex. Guesses are eliminated as higher spatial frequency information is processed, typically until one final candidate remains.

Nonetheless, if recognition processes were somehow hindered (e.g., via eye movement) and bottom-up inputs ceased, it is plausible that the object candidate with the most activation via top-down feedback should make it to conscious recognition (assuming there is sufficient activation for conscious recognition). Bar's (2004) model is theoretically sound and, much of the support for his model come from physiological studies. For instance, using fMRI, Fenkse, Aminoff, Gronau, and Bar (2006) provided physiological evidence for their model in which they found greater blood-oxygen level differences (BOLD) activation of various hypothesized brain regions (e.g., frontal, inferior, and parahippocampal areas) when participants were shown low-spatial frequency images compared to high spatial frequency images. The study is highly informative, but findings are at best correlational and do not give insight into what happens to the dynamics of the object representations. Though it must be noted categorical representations are well established in various regions of the brain (e.g., Haxby et al., 2001; Kaiser, Azzalini, & Peelen, 2016; see Contini, Wardle, & Carlson, 2017) and newer techniques are allowing the decoding of object representations (e.g., Carlson et al., 2013)—however, accuracy of decoding in early (<80 msec.) is limited. Regardless, as were discussed, behavioral support for Bar's (2004) model are ample for some aspects (i.e., context effects) but limited for other aspects (i.e., hypothesis generating) of his model.

Context Effects on Object Recognition

Though Bar's (2004) model for object recognition lacks substantial behavioral evidence, there is sufficient support for the contextual-influence aspect of his model. Many studies have strongly demonstrated that contextual scenes greatly facilitate real-world object recognition, and this should not come as a surprise as objects are rarely present in true isolation. Instead, scenes constantly accompany objects, and the relationship between the two become strong mental representations (e.g., contextual frames/schemata, Bar & Ullman, 1996). Studies on object recognition have shown clear evidence for contextual facilitation of object recognition when scenes are presented prior to and alongside an object (e.g., Palmer, 1976; Davenport, 2007; for review on contextual effects on object recognition, see Henderson & Hollingworth, 1999; Bar, 2004, Oliva & Torralba, 2007; Barenholtz, 2013). Nonetheless, contextual effects dissipate if scenes contain a violation of perceptual norms (e.g., orientation, probability, size, etc.; Biederman, Messanotte, & Rabinowitz, 1982). However, it must be noted that the research on context effects are not at a complete consensus on the importance or role of top-down factors on object perception. For instance, Hollingworth and Henderson (1998) found no facilitation in object recognition from semantically consistent scenes when response biases were controlled (for arguments against context effects, see Henderson and Hollingworth, 1999). Regardless, more compelling evidence for Bar's (2004) general model come from a study by Barenholtz (2013) in which the author demonstrated the dramatic influence of context. In short, Barenholtz found that the level of information (i.e., resolution) needed to identify an object is significantly reduced if a contextual scene is provided. The effect is even larger if participants are personally familiar with the context (e.g., the participant's bedroom). The aforementioned study provides evidence for Bar's (2004) experienced-based model of contextual facilitation. However, Barenholtz (2013) was cautious to note that participants were not under any time-constraint. Though not the point of the researcher's study, without time-constraints, participants had the ability to resolve any competition between object representations and make a conscious decision. This is the case for many visual object recognition studies.

Evidence for Multiple Candidates

Thus, is there any evidence for the coactivation of multiple object guesses—or candidates—during object recognition? Studies on the identification of ambiguous figures allude to some support of the object candidate generating stage of object recognition. Classic studies such as the well-known rat-man experiment have demonstrated that top-down processes, not only constrain, but also bias how someone recognizes the object (Bugelski & Alampay, 1961). When shown pictures of animals, people often interpreted the rat-man figure as a rat. In contrast, people perceived the figure as a man when primed with images of people. Similarly, concepts can also act as a constraint for the interpretation of ambiguous figures (Balcetis & Dale, 2007). For instance, being primed with the concept of "music" increases the probability that people will interpret the saxophone-woman figure as a saxophone player (Balcetis & Dale 2003). Even motivation strongly biases how someone interprets an ambiguous figure (Balcetis & Dunning, 2006). However, stimuli from the studies mentioned above are artificial and unrealistic; objects in the real world seldom encompass some form of duality in their identity. Regardless, some of the more persuasive evidence for the simultaneous activation of multiple representation from a single stimulus come from experiments outside visual object recognition and from studies using a lexical decision task paradigm.

Lexical Decision Task

In a lexical decision task (LDT), participants encounter a word stimuli that may or may not be real (e.g., nonsense words). Participants are traditionally tasked with indicating if the presented word is real with a button press. As such, changes in reaction times towards words should be indicative of an underlying effect such as priming. Using an LDT paradigm, Swinney (1979) demonstrated that multiple semantic meanings of an ambiguous word are activated when encountered. For instance, the English word "bug" can denote an insect or it can represent a wire-tapping device. Swinney (1979) showed that either interpretation can be facilitated via context. Swinney embedded ambiguous *prime* word stimuli (e.g., "bug") in unambiguous and ambiguous contextual sentences and then measured reaction times for lexical decision making for semantically related *target* words (e.g., "ant" for insects, "spy" for wire-tapping device; see Table 1 for example stimuli). The author found that if the context was ambiguous, both meanings of a word were activated; however, the effect was strongly biased when the context was unambiguous. Regardless, there was evidence that both meanings of a word were still activated in the strong context. Yet, one interpretation of the word “bug” is, or should be, more dominant than the other in the real world (e.g., insect > spy device). Measuring the varying levels of activation by frequency or dominance of interpretation was not the purpose of Swinney (1979), but it was the aim of Neely, Keefe, and Ross’ (1989) experiments. In their study, the researchers found that reaction time in a LDT were related to the level of dominance of the target word. More specifically, they found that when primed with a categorical word (e.g., “bird”), participants were more quickly to respond to a target word that represented a high-dominant categorical exemplar (e.g., “robin”) than a low-dominant categorical exemplar (e.g., “vulture;” Neely, Keefe, & Ross, 1989).

	Ambiguity condition	
Context condition	Ambiguous	Unambiguous
No context	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several bugs$_{\Delta}$ in the corner of his, room.	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several insects$_{\Delta}$ in the corner of his room.
Biasing context	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other bugs$_{\Delta}$ in the corner of his room.	Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other insects$_{\Delta}$ in the corner of his room.

Visual words Displayed at "Δ"	ANT	(contextually related)
	SPY	(contextually inappropriate)
	SEW	(unrelated)

Figure 2. Example stimuli and condition from Swinney (1979). Participants were instructed to make a lexical decision task for a word that was contextually and/or semantically related to an ambiguous word embedded in an (un)ambiguous sentence

Swinney’s (1979) findings suggest that it is possible to coactivate and measure multiple representations of an ambiguous stimuli. Neely, Keefe, and Ross (1989) have demonstrated that it is possible to measure that varying levels of activation for a representation based on the level of dominance. These two studies combined imply that it should be possible to measure the different levels of activation for two simultaneously activated object candidates in the early stages of object recognition.

Current Study

The general aim for the current study was to address several questions associated with competition between object candidates in early object recognition. The motivation behind this goal was the idea that misperceptions resonate from early stages of object recognition, where one candidate of an object is incorrectly chosen due to top-down factors. This idea was derived from Bar’s (2004) model of object recognition. Decades of research on object recognition have demonstrated the influential role of context on facilitating object recognition (e.g., Palmer, 1976; Bar, 2004, Barenholtz, 2013) and how it can bias interpretation of an object (e.g., Bugelski & Alampay, 1961, Flemming, Bandy, & Kimble, 2010). Thus, it is plausible to bias the interpretation of an object in early object recognition. However, limited behavioral data exist to support Bar’s (2004) proposed early stages of his model. This is partially due to the difficulty in developing a methodologically sound and objective measure sensitive enough to detect varying levels of activation from stages of processes that are hypothetically subconscious (e.g., object candidacy). This can be reconciled by using a LDT paradigm. Swinney (1979) and Neely, Keefe, and Ross (1989) both suggest that LDT paradigms are sensitive enough to accomplish this goals.

Therefore, I employed a modified LDT paradigm to (a) detect the simultaneous activation of both candidates, (b) measure the competitive relationship between them, and (c) observe the influence of context on this relationship. In the modified LDT paradigm, participants were presented with a low-pass filtered objects before participants encounter a semantically related or irrelevant word. The words were generated or gathered from various lexical databases (discussed further in detail in Methods section). All object images were used from an unpublished study (Islam & Sanocki, 2012). As a quick note, Swinney (1979), alongside much of the literature using a LDT paradigm strictly used word stimuli as their primes whereas images were used in the current study. This raises the concerning possibility of creating confounding and biased effects by simply presenting an image prime. However, Vanderwart (1984) found that both pictures and words equally facilitate lexical decision making for a target word if the prime and the target are semantically related. The researchers concluded that semantic priming, in a LDT paradigm, appears to be single-formed. Specifically, they suggested that representations are independent of the "surface" or stimulus form.

Theoretically in my proposed LDT paradigm, upon seeing a low-pass filtered image of an object, participants should formulate multiple candidates about the object (Ullman, 1995; Bar, 2004). The LDT should reflect what candidate(s) are online. Response time of a word related to a candidate relative to a control word should reflect the direction of the activation. For instance, shorter reaction times for a candidate word should reflect facilitation while slower response times would indicate inhibition. Both potential outcomes should provide insight into how the possible competitive nature of object identification. Regardless, before continuing onto specific theoretical questions surrounding the current study, it is important to establish a set of operationalized terms that coherently encompasses the goals of the study.

*Operations***.** An important feature of Bar's (2004) model of object recognition is the projection of multiple interpretations during the early stages of identification. These possible different representations, hereafter, will more accurately be referred to as *object candidates*. Previous research has found that some candidates are more frequent for a given object than others (e.g., more dominant). The frequency of such candidates was ranked in an unpublished pilot study (Islam & Sanocki, 2012) The most frequent candidate was referred to as *primary candidates*. Though multiple candidate activations were previously compared and measured, the number of candidates were limited to two for this study. Thus, primary candidates were compared to the second most frequented interpretations or *secondary candidates*. To measure activation, a LDT paradigm was used to compare reaction times for words semantically related to a candidate. Nonetheless, the words associated with primary and secondary candidates cannot be directly compared due to differences in word length and frequency. Therefore, words associated with candidates were compared to a neutral control word matched for both word length and frequency. Thus, *test words* semantically related to their candidate primes, were compared to their matched counterpart *control words*. Activation of a candidate was marked by a significant difference in reaction time between test and control words; the direction of the difference indicated the type of activation (positive or negative). Facilitative effects were marked by shorter reaction times for test words when compared to control words. Conversely, suppression/inhibition effects were inferred from longer reaction times for test words when compared to their matched control words. Finally, the LDT paradigm employed *non-words* and were paired with non-critical distractor images to serve as catch trials.

Current Goals. The present study aimed to detect activation of multiple candidates from a single object. Previous research has shown subjective evidence (e.g., open-ended responses); however, a LDT paradigm was applied to acquire more objective behavioral evidence. Moreover, if multiple activations are found (more specifically for the secondary candidate), what is the competitive relationship, if any, between the primary and secondary object candidates. Finally, the study aimed to observe if and how context effects the competition between two candidates. Does context facilitate associated candidates and does it inhibit non-relevant and competing candidates?

A few predictions were made about the following experiments. Given the physiological support for Bar's (2004) model (e.g., Fenkse, Aminoff, Gronau, and Bar, 2006; Bar et al., 2006; O'Callagrahn et al., 2017), evidence for simultaneous activation of two semantic representation (e.g., Swinney, 1979; Neely, Keefe, Ross, 1987) from lexical decision, and evidence for multiple representations from ambiguous object recognition studies (e.g., Bugelski & Alampay, 1961; Balcetis & Dale, 2003; 2007), I anticipated both the primary and secondary candidates to indicate some form of activation—whether positive or negative. I however did not make any predictions about the relationship between the two candidates. Regardless, I did predict a context effect on both object candidates. While specific predictions were limited due to the contingencies of the first experiment, both object candidates were expected to exhibit a positive effect since much of the object recognition research has showed a positive effect of context (e.g., Palmer, 1976; Bar, 2004, Barenholtz, 2013)

EXPERIMENT 1: OBJECT CANDIDATE DETECTION

Bar's (2004) model of object recognition claims that the identification process begins with a generation of multiple object candidates. These candidates are constantly refined and/or eliminated with the addition of incoming higher levels of information and top-down factors such as context. However, if the process were to be interrupted at this critical stage and bottom-up inputs ceased, the brain might be forced to pick between multiple candidates. Theoretically, the candidate with the strongest level of activation (presumably from top-down feedback) would be chosen. This process can potentially result in misperceptions if the incorrect candidate is chosen. However, there is little evidence to suggest that multiple candidates are coactivated. Using a modified LDT akin to Swinney (1979), Experiment 1 aimed to (a) detect the simultaneous activations of multiple object candidates and (b) measure the relationship between these candidates.

METHOD

Participants

Thirty-four undergraduate students from Florida Atlantic University were recruited through the university participant pool or undergraduate psychology courses. Participants received course credit for their involvement and were required to have normal-to-corrected vision.

Stimuli

A modified LDT paradigm was used in the current study. In this paradigm, a low-pass filtered image of an object preceded all word stimuli. In addition to images, word stimuli were gathered from two empirically validated lexicon databases; details of each stimuli type follow.

Lexicon. All real word stimuli were generated and gathered from the English Lexicon Project (Balota et al., 2007). Three sets of words were categorized. The first set of words consisted of real "test" words. These words were semantically relevant to an object candidate. For instance, a word used for the object *lighter* could have been "FIRE" or "SMOKE." The test words were used to measure priming effects of an object candidate. Theoretically, the test words should be sensitive to the levels of activation of an object candidate. To measure such effects, test words were compared to a baseline "control" words. Control words were matched for both word length (i.e., number of letters in the word) and word frequency (i.e., how often the word appears in written text in the real world) to their test word counterparts. Control words were not semantically relevant to any object candidate from any object stimuli. Finally, the third set of words were "non-words." Non-word stimuli appeared very similar to real words commonly used in the English language; however, the words do not encompass any semantic meaning or definition. All non-words were derived from the ARC non-word database and contained pseudomophones (Rastle, Harrington, & Coltheart, 2002). Additionally, non-word stimuli were randomly chosen from a randomly generated pool for 200 non-words. The non-word stimuli were used to assure that participants accurately performed the LDT. Finally, non-words were only paired with distractor object images in catch-trials. Ninety-six unique word stimuli were used. Half of the words were non-word stimuli to keep half of all general trials to be distractor trials. The remaining half of words were equally split into test and control categories. Word length ranged from three to 12 letters.

For specificity and simplicity of the various conditions of the current study (further elaborated later), “test” and “control” words will be referred to by the object candidate (primary or secondary) they were intended to test or control. For instance, a test word aimed to test a primary candidate was referred to as a “primary test” word. Similarly, a control word used as a control for a secondary candidate was referred to as a “secondary control” word. In summary, the object candidate (primary/secondary) and the category it served (test/control) labeled the words. Refer to Table 2 for sample stimuli.

WORDS	NON-WORDS
LIPS	EALS
ANIMAL	SHEEKE
GUITAR	PLOOME
FOOTBALL	STINTZAK

Figure 3. Lexical stimuli used in the current study. Real words and non-words were matched for word length. Real words were attained from the English Lexicon Project (Balota et al., 2007) and non-words were generated from the ARC Nonwrod Database (Rastle, Harrington, & Colthear, 2002).

Object Images. The object images that were used in this study conveyed similar levels of information posited by Bar (2004) in early object recognition. That is, all objects were low-pass filtered. Moreover, the stimuli that were used in this study was gathered, processed, and normed for accuracy, interpretations, and confidence in a previous unpublished pilot study (Islam & Sanocki, 2012). In the study, many low spatial frequency object images were found to be ambiguous due to limited resolution (i.e., LSF), producing multiple interpretations of the objects from participants. In short, these interpretations were normed and ranked across approximately 500 participants. The most frequently observed interpretation of an object was labeled as the “primary candidate.” The second most frequent response to an object was categorized as a “secondary candidate.” Again, “candidate” refers to the candidacy of an object interpretation in the hypothesis-refinement stage of the recognition process. Nonetheless, all object stimuli were gathered from numerous online databases and then image processed (i.e., low-pass filtered) using Matlab Software. All objects were presented in isolation, in front of a white background, with an 800 x 800 resolution. Refer to Figure 2 for example stimuli. Thirty-six unique objects were used in the study; many the objects were distractor objects to match presentation rates of critical test trials. Two pilot experiments were conducted for the current experiment and verified no intrinsic differences between test and control word stimuli. Additionally, the experiments ensured simple image presentation did not influence the LDT.

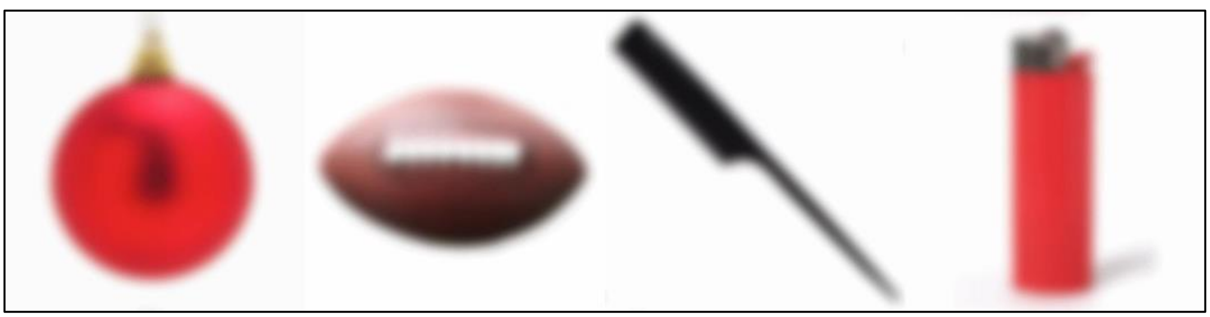

Figure 4. Sample low-pass filtered object images used in a previously unpublished study. From left to right, the objects (and second most frequented interpretation) are: Christmas ornament (apple), football (lips), hair comb (razor), and lighter (fire extinguisher).

Procedure

After participants completed their informed consents, they were seated in a low-lit and quiet room where they participated in the experiment. The experiment was generated by Xojo Software using BASIC. Each trial began with a 1000 msec. cross-shaped fixation point presented in the center of the screen. Afterwards, a low-pass filtered object presented in isolation were presented for 70 msec followed by a 70 msec presentation of a colorful mask matched for spatial frequency. Participants then encountered the LDT as previously discussed. Upon making a response using the computer mouse (left click = “yes/real”, right click = “no/non-word”), participants encountered a text field in which they were instructed to type in what they believed the object to have been. Participants were limited to one guess and were instructed to be specific as possible. After submitting their response, a new trial began (see Figure 3 for visual representation of trials). One purpose of identification task was to assure that participants attended to the object image—this alleviated the concern that participants could have simply ignored the image and only respond to the LDT stimuli. There was a total of 96 experimental trials (48 non-words, 48 primary/secondary test/control words). Additionally, there was 12 training trials before the main experiment. The first two trials in the training block consisted of slower presentation times to ease participants into the experiment. In the first trial, object and mask presentation times were initially 300 msec. These presentation times were reduced to 150 msec. in the second trial. The third trial and all following trials in the experiment returned to the 70 msec. presentation time. The experiment took 30 to 40 minutes.

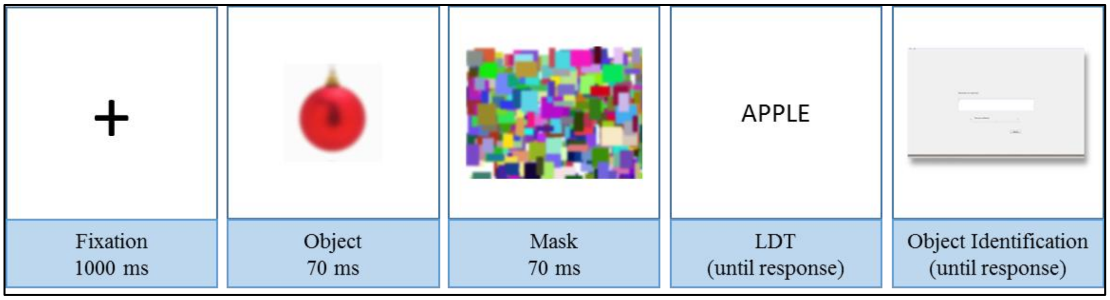

Figure 5. Schematic representation of trials in Experiment 1. Dual task LDT with objects present (identification required). All trials began with a 1000 msec. presentation of a fixation point followed by a 70 msec. presentation of a low-pass filtered object and another 70 msec. presentation of a pass-filter matched mask. A word stimuli was then presented on screen until a response was made. Upon making a key-press, an auditory beep signaled the registration of the response. Participants then encountered a text field in which they identified the previous seen object. A new trial began immediately after.

RESULTS AND DISCUSSION

Paired-samples *t*-tests were used to analyze activity levels of object candidates. Specifically, differences in LDT reaction times between test and control words within an object candidate type were analyzed. Additionally, LDT reaction times were analyzed for trials in which the LDT was accurately performed (approximately 93% of all trials). When the word stimuli were consistent with primary object candidates, paired-samples *t*-tests revealed no significant differences in reaction times between test (M = 1.78, SE = 0.10) and control (M = 1.70, SE = .10) words; $t(33)$ = 1.38, p = *n.s.*, SE = 0.06. Nonetheless, within secondary object candidates, participants responded significantly slower to test words (M = 2.02, SE = 0.12) than control words (M = 1.50, SE = 0.09), $t(33)$ = 2.92, $p < 0.01$, SE = 0.09. Non-words (M = 1.50, SE = 0.07) were not intensively analyzed nor compared to any other conditions as they are not the focus of the current study (see Figure 6).

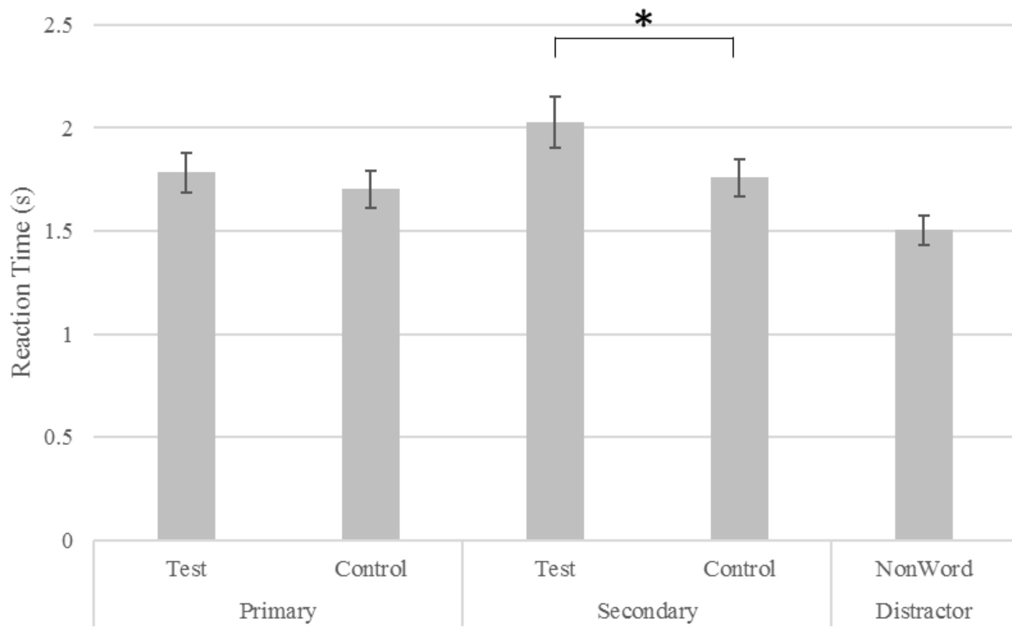

Figure 6. Mean LDT reaction time and SE of Experiment 1. Participants were significantly slower reacting to secondary test words compared to secondary control words. No differences were observed in the primary candidate conditions.

Initially, I predicted that both candidates would demonstrate signs of activation—this was partially observed. First, significant differences in reaction time between secondary test and control words imply some level of activation—though activation in this instance was negative. Moreover, the results suggest that secondary candidates are suppressed. The lack of difference between primary test and control words indicate no activation of the primary. This is surprising because the primary candidate is (1) most likely the true identity of the object and (2) previous experiments have demonstrated that the primary candidate is the most frequented interpretation. Nonetheless, after coding individual open-ended responses, results revealed approximately 79% of open-ended responses for critical trials in the current experiment were consistent with primary object candidates. Therefore, it can be argued that the primary candidate was active during object recognition; however, it may not be within the window of time in which responses were recorded (i.e., LDT). Studies such as Swinney's (1979) have demonstrated that multiple representations can be coactivated; but such studies did not have a heavy time constraint such as the current experiment. The lack of a time constraint might allow representations to develop. Regardless, referring to the first goal of the current experiment, it cannot be definitively concluded that multiple object candidates can coactivate *simultaneously* in the earlier stages of object recognition. However, it does appear that there is a form of competition in which secondary object candidates are actively inhibited. The source of the suppression may be from high level areas as Bar (2004) suggests, yet it may be from the primary candidate itself. Though facilitation of the primary candidate was not observed, there may have been enough time between stimulus presentation and participants performing the LDT for the primary candidate to become active and suppress the secondary candidate.

Alternatively, inhibition may have been a result of priming stimuli being difficult to identify. In the current experiment, the LDT was implemented to be sensitive to activation of the object interpretations they represented. This was possible because the word stimuli were sensitive to prime effects from the preceding pictures of the objects. Typically, a prime increases the response speed of a following test stimuli if both stimuli type are consistent or relevant, this is especially true for words (e.g., Balota, 1983). However, there are situations in which a prime may decrease response times for consistent test stimuli; this is referred to as "negative priming" (Tipper, 1985). First studied under lexical decision paradigms, it was found that if the prime stimulus was weak or difficult to perceive (e.g., suprathreshold presentation, back masking) or the representation was weak (e.g., infrequent), semantically related test stimuli that came after would take participants longer to respond to than a stimulus that was incongruent (e.g., Tipper, 1985; Carr & Dagenbach, 1990; Anderson & Spellman, 1995). While the exact mechanisms are still debated (for overview, see Kahan, 2000; Tipper, 2001), Carr and Dagenbach (1990) has suggested a *center-surround inhibition* model to explain such effects. Inspired by the neurophysiological center-surround mechanisms, Carr and Dagenbach proposed that a prime activates a *central* representation of a prime and a suppressive spreading activation in the *surround* that inhibit competition from nearby representations. This aids in relieving competition, ensuring "codes" related to the prime rise to consciousness. However, if the prime is weak (e.g., lacking sufficient information or a weak representation) and fails to reach the threshold for consciousness, then the inhibiting spread is left, actively suppressing all related codes. The latter situation produces negative priming. In the center-surround inhibition model, facilitation of primed stimulus is rarely found (Carr & Dagenbach, 1990). Rather, a null-prime is typically observed for strongly presented or related primes and negative primes are found with weakly presented or related primes. Since then, it has been suggested that the spread activation from a prime is not limited to just semantically related "codes," rather the spread can activate or inhibit codes related by features (Anderson & Spellman, 1995). For instance, a prime of "tomato" with features of 'round' and 'red' may suppress the stimuli "BLOOD" because of the shared associated feature of 'red.' Additionally, this model has been extended to methodological paradigms in which a picture prime precedes a word stimulus with similar results (e.g., Stone, 2012).

Relating to the current study, Carr and Dagenbach's (1990) findings are consistent with the current results. The prime in the current experiment was limited by a short presentation time (70 msec), limited resolution (low-pass filtered), and backward masking. Primary candidates (with stronger representations) in the current experiment displayed no facilitation; however, less related and frequented secondary candidates (with weaker representations) demonstrated inhibition. The center-surround inhibition model may apply to the current findings, but should be done so cautiously.

Nonetheless, the findings of the first experiment imply an active suppression of the secondary candidate with little evidence for the simultaneous coactivation of the primary candidate. What remains unclear is the source of the suppression. Testing the effects of context may more clearly reveal the potential relationship between the two object candidates. For instance, will context facilitate semantically consistent object candidates? Specifically, will secondary consistent context mitigate the inhibition or can it even facilitate the secondary candidate?

EXPERIMENT 2: CONTEXTUAL MODULATION OF CANDIDATES

In addition to measuring competition of object candidates in the early stages of object recognition, a secondary goal of the current study was to observe possible context effects on such candidates. If the intake of bottom-up information is disrupted during the elementary stages of Bar's (2004) model and object recognition is hindered, then it may be possible to facilitate an incorrect object candidate into the conscious perception via an inappropriate context. Many studies have demonstrated the strong facilitative effects of context (e.g., Palmer, 1976; Bar, 2004, Barenholtz, 2013). Other studies have shown that the perceived identification of an ambiguous figure can be strongly influenced by top-down factors such as context and motivation (e.g., Bugelski & Alampay, 1961, Flemming, Bandy, & Kimble, 2010). However, many studies utilized very artificial stimuli dissimilar to real life objects (e.g., duck-rabbit). Experiment 2 attempted to adapt methods of Swinney (1979) and Neely, Keefe, and Ross (1989) to context-based visual object recognition.

Images of natural scenes served as context and preceded LSF object presentations. Congruent context were scenes that are semantically related to an object candidate; conversely, incongruent context were scenes that are semantically irrelevant to an object candidate. For critical trials, congruent scenes were related to one object candidate but incongruent to the other object candidate.

METHOD

Participants

Fifty undergraduate students from Florida Atlantic University were recruited through the university participant pool or undergraduate psychology courses. Participants received course credit for their involvement and were required to have normal-to-corrected vision.

Stimuli

In addition to the lexical and object stimuli used in Experiment 1, the current experiment utilized images of natural scenes that may or may not be semantically relevant to an object candidate. These scene images were presented at 800 x 800 resolution, full color, and were not pass-filtered. Specifically, there were three main types of scenes: scenes congruent to a primary object candidate but not the secondary, scenes congruent to a secondary object candidate but not the primary, and scenes that are incongruent to both primary and secondary candidates. Scenes that are incongruent to either types of candidates of interests were paired with non-critical objects (i.e., distractor trials). Scenes congruent to a primary candidate were labeled as *primary scenes*; similarly, scenes congruent to the secondary candidate were labeled as *secondary scenes*. Scenes did not contain any objects or object candidates used in the experiment.

Procedure

Participants were seated in a low-lit and quiet room after completing their informed consent. They sat approximately 2 ft. in front of the computer scene where they performed the experiment. All trials began with a 1000 msec presentation of a cross-shaped fixation point centered on the screen. Afterwards, a scene image appeared on the screen for 1000 msec. Participants encountered a low-pass filtered object followed by a colorful mask, both on screen for 70 msec. each. Participants were then tasked to perform a LDT. After hearing a beep indicating a response, participants were presented with a screen asking them to identify the object. Upon submitting their response, a new trial began (refer to Figure 4 for example trial). There was a total of 96 experimental trials for each participant (48 non-words, 48 primary/secondary test/control words). Before the test phase, participants completed 12 training trials. The first two trials in the training block consisted of slower presentation times of both the object and mask. The first trial were 300 msec. stimuli (both object and mask) presentation and the second trial were 150 msec. The third trial and all following trials in the experiment returned to the 70 msec. presentation time. Note that the scene presentation time remained 1000 msec. throughout all of training. The experiment took approximately 40 minutes.

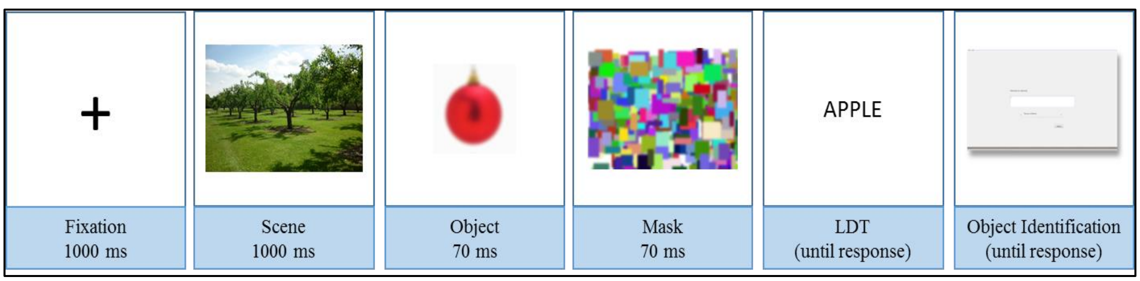

Figure 7. Schematic representation of trials in Experiment 2: Contextual modulation. All trials began with a 1000 msec. presentation of a fixation point. Afterwards, an image of a scene was displayed on screen for another 1000 msec. Participants then saw a 70 msec. presentation of a low-pass filtered object and another 70 msec. presentation of a low-spatial frequency mask. After the mask, a word stimuli remained on screen until a response is made. After hearing a beep, participants encountered a text field where they were tasked to identify the object (not the scene). Upon response submission, a new trial began.

RESULTS AND DISCUSSION

To reduce too many repeated presentations of object stimuli, participants in Experiment 2 were split into two groups in which participants were only tested on words consistent with the primary object candidate or secondary object candidate. However, participants in both groups viewed both scene types. Analyses for the data from the current experiment were similar to analyses from the previous experiment. Again, paired-samples *t*-tests were conducted on trials where participants made accurate responses to the LDT (approximately 91% of all trials).

Paired-samples *t*-tests revealed no significant differences between primary test (*M* = 1.64, *SE* = 0.07) and control words (*M* = 1.68, *SE* = 0.8) when primed with scenes consistent with primary candidates, *t*(21) = 0.88, *p* = *n.s.*, *SE* = 0.05). However, reaction times for primary test words (*M* = 1.65, *SE* = 0.07) were shorter than control words (*M* = 1.76, *SE* = 0.9) when primed with secondary candidate consistent scenes, *t*(21) = 2.53, *p* = 0.02, *SE* = 0.04. Again, non-words (*M* = 1.55, *SE* = 0.07) were not intensively analyzed nor compared to any other conditions. Refer to Figure 6 for graph of mean RT and SE's for the LDT.

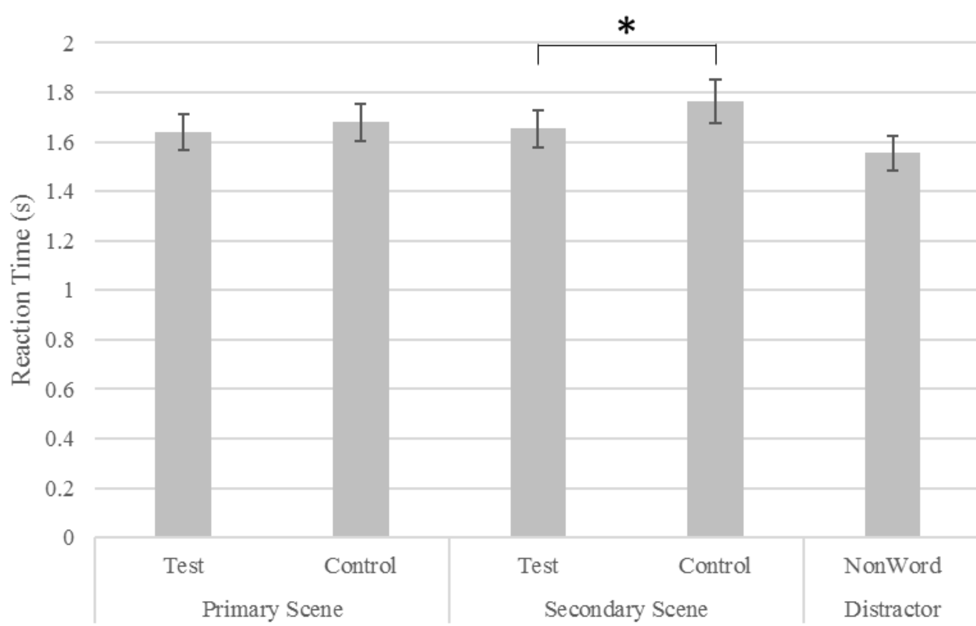

Figure 8. Context effects on primary candidate word stimuli. When primary candidate words were primed with primary candidate scene words, no significant differences in RT

was observed for the LDT. However, when primed with secondary candidate consistent scenes, participants performed the LDT faster.

Participants ($N = 28$) in the first group only viewed words consistent with secondary object candidates. When primed with primary candidate consistent scenes, paired-samples *t*-tests revealed no significant differences between secondary test (M = 1.61, SE = 0.07) and control words (M = 1.71, SE = 0.06), $t(27) = 1.73$, $p = n.s.$, SE = 0.05. However, when primed with secondary candidate consistent scenes, participants responded significantly slower to test words (M = 1.67, SE = .07) than to control words (M = 1.53, SE = 0.06), $t(27) = 3.68$, $p < 0.01$, SE = 0.04. Non-words (M = 1.50, SE = 0.06) were not intensively analyzed nor compared to any other conditions. See Figure 7 for mean reaction time and standard errors for the LDT.

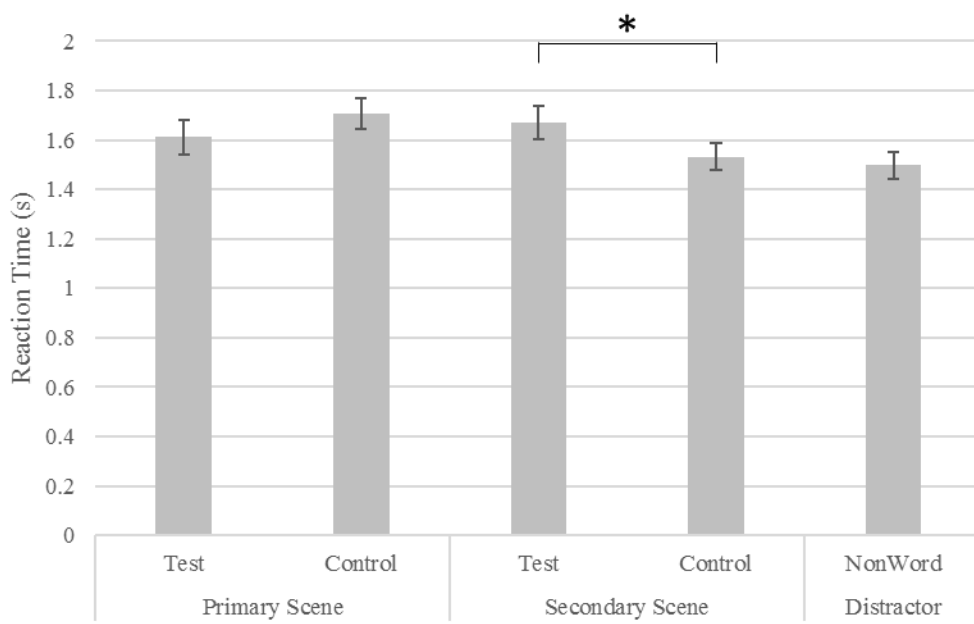

Figure 9. Context effects on secondary candidate word stimuli. When primed with primary candidate consistent scenes, no significant differences in LDT RT was observed between control and test words. However, when primed with secondary consistent scenes, test words displayed longer RT's than control counterparts.

Contrary to what was predicted, the results do not provide any evidence for the primary candidate to facilitate when primed with a semantically related scene. This is somewhat contradictory to studies on context based object recognition that have frequently shown facilitative effects of a semantically consistent scene on object identification (e.g., Palmer, 1975; Biederman, Messanotte, & Rabinowitz, 1982; Bar, 2004, Davenport, 2007, Barenholtz, 2013). More interestingly, the primary candidate *did* show evidence for facilitation when primed with a scene consistent with its competitive secondary candidate.

When secondary candidates were primed with a relevant scene, the results suggest that the candidates exhibited suppression. This may be a result from competition from the primary candidate. Alternatively, it may be a result of center-surround inhibition (Carr & Dagenbach, 1990). However, traditional center-surround inhibition requires that the prime (i.e., the scene) be relatively weak in some manner (representation or available information). In the current experiment, the scene was displayed on screen for 1000 msec. without any pass filtering. This should have been ample time for participants to process the scene. Nonetheless, Stone (2012) found that center-surround inhibition is still creates negative priming when primes are fully visible and recognizable. The researcher proposed a modified version of Carr and Dagenbach's (1990) model. In short, Stone (2012) proposed that negative priming has a sensitive window of effect between 50-1000 msec. stimulus onset asynchrony (SOA). Stone tested prime effects of pictures of famous people on labels of their names and observed a small positive prime effect when SOA's were below 50, strong positive prime when SOA's were above 1000 msec, and a very strong negative prime in between. The time between the stimuli, in the current experiment, to disappear to when the LDT appears falls within this negative prime window. Nevertheless, Stone's (2012) modified center-surround inhibition model cannot account for the positive prime observed when primary candidate was primed the secondary scenes[1]. This result is surprising and, to my knowledge, no results like this exist in the current literature.

Overall, the results of the second experiment appear to be somewhat contradicting to the current literature—no object candidates were facilitated when primed with a semantically relevant scene, primary candidates were facilitated when primed with a competitive scene, and the secondary candidate was suppressed when primed with a consistent context. The findings of the current experiment should be combined with the findings of the first experiment to create a more coherent explanation.

[1] Stone (2012) does suggest that stimuli with stronger activation levels will follow a similar positive-negative-positive prime pattern observed in her study. Nonetheless, due to elevated activation levels, the results may appear to be either null or facilitative. This suggestion; however, was only speculative.

GENERAL DISCUSSION

In Experiment 1, no facilitation of primary candidates was detected. Moreover, a strong suppression of the secondary candidate was observed. In Experiment 2, context was added and the results indicated that primary candidates still did not demonstrate any signs of facilitation, even when primed with a semantically consistent scene. Facilitation was found when primary candidates were primed with secondary consistent scenes. Nevertheless, no facilitation was detected for secondary candidates when primed with consistent scenes. Rather, a suppression effect akin to Experiment 1 was found. However, the suppression dissipated when the secondary candidate was primed with a primary scene.

Going back to the original aims of the current study, what do these results imply? The first objective was to detect *simultaneous* coactivation of multiple object candidates. The combined results of the present study suggest that multiple candidates are not coactivated given the lack of statistical significance within the primary conditions. However, varying levels of suppression of secondary candidate in relation to varying effects of activation of primary candidate across multiple contexts suggest that both candidates are active at one point during the recognition process (later elaborated). A second goal of the current study was to observe the competitive relationship between primary and secondary candidates. Experiment 1 demonstrated the “resting” state of these candidates in which no positive activation was detected for the primary, but a negative activation was shown for the secondary. As stated above, one plausible cause was the primary candidate inhibiting the secondary; alternatively, the suppression may have originated from a second, higher-level source. However, when primed with secondary consistent scenes, primary candidates were facilitated. This is significant because this is the only condition in which the primary candidate showed any signs of activation. This implies that the primary candidate is online at some point of the object recognition process and suggests that suppression may originate within the primary candidate. The last aim of the present study was to examine the role of context on object candidates. Context appears to reinforce an already biased object interpretation (i.e., primary candidates), but fails to change the bias itself.

Nonetheless, taken together, the combined results of the current study are, to the best of my knowledge, not explained by any current theory or models found in the literature. However, I theorize one possible mechanism that may explain these results. I propose that the initial stages of early object recognition are biased towards the most frequented candidate (primary). This bias appears to come in the form of an inhibition. It appears that the primary candidate actively suppresses competition from lesser candidates. This effect is strengthened when the primary candidate is challenged, but eliminated when it is reaffirmed. By actively suppressing competition, top-down processes can “default” to the more active primary candidate even if it is at a neutral state.

So why do participants respond with the primary object candidate? The current study looked at a relatively early window of object recognition (<70 msec.). By no means is object recognition a static process, instead it is a temporally dynamic system. It is plausible that in the earlier stages of object recognition is inhibitory and the latter is faciliatory as suggested by Stone (2012). Of course, future studies should test these ideas. Specifically, future research should examine the relationship between candidates throughout a longer time period to analyze temporal dynamics of candidates. Additionally, more research is needed to study the relationship between a network of candidates (i.e., more than two). It may be that the levels of suppression correlate with the frequency of the interpretation. Furthermore, the role of truly incongruous context need to be assessed. The incongruous context in the current experiment was still related to both candidate because of the competitive relationship they share. However, what was not tested was a third set of scenes which are not related to any form of the candidates. It is also worthwhile to conduct a version of the current experimental paradigm in which the object stimuli are embedded into the scene image. Studies have shown that object identity is heavily biased when it is surrounded by the actual context (e.g., Oliva and Torralba, 2007), what is unknown is what happens to other interpretations. Finally, studies should examine the factors that make a primary candidate "primary." Is it familiarity, expertise, emotional attachment, or something else?

Referring to the very first concern posed in the beginning of the paper—can misperceptions occur from the presentation of an inappropriate context? The findings of the current study suggest no—at least, not easily. Misperceptions in the real world are infrequent. This may indeed be the case because competition from inappropriate interpretations are actively suppressed. Regardless, misperceptions *do* occur. The current study suggests that context effects may only be a small part of a much more complex system that induces such errors in perception.

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