Investigating the Proposed Mechanisms Guiding Negative Attentional Templates

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DEDICATION

I dedicate this thesis to my grandfather, my pal, Kevin O'Leary.

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Thank you to Dr. Caglar Tas, who has had the strongest influence in molding me into the scientist I am today. Your passion for your students, especially your passion for them reaching and surpassing their goals, is something I will cherish for years to come. Thank you to the members of my committee, Dr. Aaron Buss and Dr. David Sutterer, for their guidance and support with developing and completing this project, and as mentors as I completed my degree.

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ABSTRACT

To complete goal-directed visual search, information that is gathered in working memory must be sorted by relevancy to the current task. In order to bias search, attentional templates are created within the construct of visual working memory (VWM) using both endogenous and exogenous information. While most attentional templates are built around positive information, which is directly relevant to the target of search, there are cases where *negative* information, which is directly relevant to the search but not necessarily the target itself, may be more efficient. However, the mechanisms behind how these negative templates direct search is debated. The goal of this study was to test differing accounts of negative template use, as well as to introduce a novel manipulation to the literature to further investigate these accounts. The results of this study support the "register-and-destroy" account of negative template use, as well as the feature/location-based account. However, they do not support the automatic rejection or search-and-destroy accounts, nor can these effects be explained by practice alone.

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CHAPTER ONE

INTRODUCTION

Visual attention is often studied through goal-directed visual search tasks, usually consisting of a target item placed within a crowded environment of distracting objects. In a typical visual search task, subjects are given information about the target prior to search and must report they have found it by identifying one of its features. The visual system uses this prior information to create an *attentional template,* an internal representation of relevant information about the goals of a task used to bias search. (Duncan & Humphreys, 1989; Carlisle et al., 2011). Typically, participants are informed about the target feature (e.g., red circle) before they search for the target among other distractors (e.g., blue and green circles). This type of positive template has been shown to speed up visual search compared to trials where no cue or a neutral cue (e.g., black circle) was given (Bundesen, 1990; Woodman & Luck, 2007).

How cues matching distractor features (instead of targets) may influence search mechanisms has become a recent topic of debate. Conflicting evidence has arisen as to whether these *negative templates* lead to differences in the selectivity of attention. While some researchers have proposed that the visual system automatically attenuates distractors matching negative cues, leading to a perceptual suppression of those distractors during search (Woodman & Luck, 2007; Arita et al., 2012; Carlisle & Nitka, 2019), others have suggested either a strategic suppression of these distractors (Beck & Hollingworth, 2015; Becker et al., 2015; Beck et al. 2018) or initial attentional capture by those cued distractors followed by strategic suppression (Moher & Egeth, 2012; Berggren & Eimer, 2020).

Early work done by Woodman and Luck (2007) examined whether representations of object features stored in working memory biased visual search in favor of memory matching objects. They hypothesized that attention would be uncontrollably captured by those objects,

regardless of their status as a target or distractor. In their search task, subjects were first given a colored cue, where the color was either target-matching (positive), distractor-matching (negative), or irrelevant (neutral). They were then presented with an array of colored outlines of squares, each with a singular gap in a side of the outline. The target object of every trial had a gap on either its top or bottom side, and subjects responded that they had found the target by pressing the corresponding up or down arrow key. To test the efficiency of cue use, the average reaction times (RTs) of each of the cue conditions were compared. It was expected that, compared to neutral cues, positive cues would elicit faster RTs indicating that attention was captured solely by target-matching objects, speeding search; negative cues would have slower RTs than neutral cues due to attentional capture by distractor objects, slowing search. Surprisingly, they found that when given negative cues, subjects had RTs *faster* than neutral cues, indicating no attentional capture by distractors. This finding led to the conclusion that negative cues could be used to create a "template for rejection," where distractors were automatically suppressed by the visual system and not attended to at all.

However, Moher and Egeth (2012) used a similar design but produced the exact opposite results. Importantly, there were only two cue conditions of negative and neutral, where the negative cue always matched a distractor. Instead of using outlined squares, subjects were tasked with discriminating between letters, where capitalized letters were targets and lower-case letters were distractors. The results showed the exact opposite of what Woodman and Luck (2007) found; RTs in negative cue trials were significantly slower than RTs in neutral cue trials. Therefore, subjects' attention was in fact captured by distractor objects, slowing search. They proposed that instead of an automatic rejection of distractors, subjects were actively attending to

them using a *search-and-destroy* strategy where cue-matching objects were searched through first before moving to objects with other features.

At this crossroads, and throughout the remainder of the literature, there are two proposed theories supporting dichotomous trends. As proposed by Woodman and Luck (2007), "automatic control" describes the visual system as rejecting the initial use of distractors, thereby forming a template for rejection. As proposed by Moher and Egeth (2012), "strategic control" describes the visual system as rapidly creating a strategy for search based on the task and environment, where distractors may be initially captured in given circumstances. Efforts to explore the possible reasons for these two competing accounts have produced relatively mixed results.

In their effort to define the negative template effect, Arita et al. (2012) used a design similar to Woodman and Luck (2007). Objects were presented around the circumference of an imaginary circle, with objects of opposing colors occupying either side of the display (e.g., red objects would occupy the left hemifield and green objects the right, split down a vertical midline). Like Woodman and Luck (2007), subjects were given positive, negative, and neutral cues and were tasked with reporting whether the target opening faced up or down. Results showed that, just as Woodman and Luck had found, negative cues showed an RT benefit compared to neutral cues, strongly supporting the automatic control account. RT benefits are even shown to increase in efficacy as set sizes increase (with 4, 8, and 12 objects). These results have been replicated, contributing robust support for the automatic account (Exp. 1, Beck & Hollingworth, 2015; Carlisle & Nitka, 2019; Zhang et al., 2020).

Alternative Accounts

The validity of using a hemifield array design using two colors, despite strong results, has been questioned. Does the design of the task influence strategic use of negative templates? Three

alternative hypotheses regarding the mechanism behind templates for rejection have been proposed.

In one hypothesis, the locations of the targets and distractors are recoded as positive templates. To test this account, Beck and Hollingworth (2015) introduced a directional cue which pointed to one of the hemifields. They also included two different search screens, where objects were either segregated by color (as with Arita et al., 2012) or intermixed randomly across the screen (similar to Woodman and Luck (2007)). When given a segregated array, the results supported the automatic control account where negative cue RTs were faster than neutral. However, when given an intermixed array, the results supported the strategic control account where negative cue RTs were slower than neutral cues.

In another hypothesis, a positive template is constructed around the colors of the objects, leading to a recoding of the cue color. This account seems substantial when only two colors are presented on a given trial, as is the standard for investigating negative templates. To test this, Becker et al. (2015) replicated the Arita et al. (2012) design in one experiment, but in another had modified the design by increasing the potential uncued distractor colors. Arrays were designed with the objects in one hemifield uniform in color while the other hemifield included a random assortment of colors (and in the negative cue condition, one of those colors is always cue-matching). In the first experiment (the Arita et al. (2012) replication), they found results almost identical to Beck and Hollingworth (2015), where negative cues showed an RT benefit. However, in their multi-colored distractor design, the results showed an RT cost for negative cues. In addition to testing the color recoding account, the location account was also tested; interestingly, there was no significant difference between negative and neutral RTs.

In response to the location-based account, Carlisle and Nitka (2019) included an experiment that replicated Exp. 1 of Becker et. al (2015). In contrast to Beck and Hollingworth (2015) and Becker et al. (2015), the results supported the automatic control account where negative cues speeded up the responses in both segregated and intermixed arrays. These conflicting results show that not only are the mechanisms underlying negative template use clearly unknown, but even that the design of the presented task itself may influence how the visual system uses negative cues.

In a final alternative hypothesis, Berggren and Eimer (2020) proposed that previous results of negative cue benefits could have been influenced by habituation, especially considering the high number of trials subjects were typically given. When analyzing their data, they binned RTs by tertiles to understand how RTs changed over the length of a given block. Each tertile corresponded with the early, middle, and late trials of each block. Consistent with expectations with habituation, average RT was heavily skewed over time; there was often a strong RT cost for negative cues in the 1st tertile, followed by diminished costs by the 2nd, and little to no cost by the 3rd tertile. From this finding, it can be inferred that simply reporting mean RTs may be misleading and does not support a mechanism for templates for rejection, owing to the early RT cost in each block. If the mechanism were to be an automatic rejection of distractors, this cost would not be present.

Neuroimaging and Eye-tracking

Though there has been minimal use of neuroimaging techniques to investigate negative templates, the results have been as mixed as behavioral results. Functional magnetic resonance imaging (fMRI) data has shown that there is a significant down-regulation of neural activity when subjects were presented with negative cues compared to positive and neutral cues. Activity

was significantly lower in the visual cortex, which contrasts with an enhancement of activity with positive cues. (Reeder et al., 2017). And further, positive cues have shown distinct patterns of activation in early visual areas, whereas negative cues have shown no such activation (Reeder et al. 2018). Therefore, regardless of the mechanisms behind the guidance of attention, negative information is processed differently by the visual cortex than positive information.

In investigations using electroencephalography (EEG), the results have lent more directly to the debate at hand. The event-related potential (ERP) components observed included the N2pc, which is implicated in attention to and the encoding of target-matching objects (Eimer, 1996; Foster et al., 2017) , and the P_D, which is implicated in the suppression of attention to distractors (Sawaki & Luck, 2010). The assumption under an initial capture account would be a delayed N2pc component when given a negative cue, as attention would be captured by distractors early in a trial. However, Carlisle & Nitka (2019) did not find an N2pc contralateral to the target side even when subjects are given negative cues, suggesting there is no initial capture by distractors. On the contrary, Berggren & Eimer (2020) found a delay in the initiation of the N2pc, but perhaps more interestingly, this delay was only accompanied by a P_D after excessive practice. This would indicate that the attentional system does not initially inhibit distractors unless a strategy is built within the template to attempt their avoidance (and this is only seen, again, after excessive practice). Indeed, this finding is supported by eye-tracking data as well; subjects are far more likely to fixate on a cue-matching object first. Therefore, when given a negative cue, the initial target of both covert attention and initial saccades are to a distractor object (Beck et al., 2018).

Though the current study will not include neuroimaging, this previous work strengthens the argument that the mechanisms behind negative template use are still debated.

Present Study

The present study will aim to test whether differences in task design can provide an explanation for contradictory results. Previous studies have investigated differences in stimulus presentation (Beck and Hollingworth, 2015; Becker et al., 2015; Carlisle and Nitka, 2019), stimulus onset latency (Zhang et al., 2020), and repeated exposure to the same cue meaning (Berggren & Eimer, 2020). However, these experiments have consistently organized trials by one cue meaning per block. Novel to the literature, this study will instead randomize the order of each trial's cue meaning so that subjects cannot predict the cue on successive trials. If templates for rejection automatically reject distractors, speeding search, then randomizing cue meanings should have no effect on search performance. RT benefits for negative cues should stay consistent across cue meanings, with little to no difference between positive and negative cue performance. Likewise, if negative templates are used strategically depending on the task, then there will be a significant difference between positive and negative cue performance. It should be noted that templates for rejection may simply be attributed to practice effects, and therefore may not be a credible explanation for the construction and use of negative templates.

CHAPTER TWO

METHODS

Experiment 1

Participants

To estimate an expected sample size, effect sizes were gathered from Becker et al. (2015), as it reported partial eta-squared (η_p^2). Using their conservative $\eta_p^2 = .18$, an alpha (α) = .05 and a target Power of .95, the estimated sample size was determined to be seventy-two subjects. Seventy-seven participants were recruited through the University of Tennessee Psychology participant pool. They were between 18-30 years of age and were screened for color deficiency using Ishihara's tests. Post-hoc exclusion criteria included poor accuracy (raising the 75% threshold set by Beck and Hollingworth (2015) to 80% to eliminate suspicion of random guessing) as well as an incomplete dataset. Only one subject's data were removed.

Stimuli

The experiment was designed using Psychtoolbox (Brainard, 1997; Pelli, 1997; Kleiner et al, 2007) in MATLAB. Subjects sat 94cm away from an ASUS 3D Vision monitor with a resolution of 1920 x 1080 and running at 120Hz. The screen background was gray (9.9 cd/m^2) with a black fixation cross (size 0.3 degrees of visual angle, dva). Stimuli were Landolt C's created as images in Adobe Illustrator (1.2 x 1.2 dva) and were one of six colors: red (x = .626, y = .334), green (x = .286, y = .597), blue (x = .143, y = .068), cyan (x = .190, y = .259), magenta (x = .252, y = .124), and orange (x = .457, y = .465). Gaps on the rings were 0.2 dva and faced one of eight directions: 0˚, 45˚, 90˚, 135˚, 180˚, 225˚, 270˚, and 335˚, with target objects having gaps at 90° or 180° (facing directly up or down). Cues were colored squares (1.2 x 1.2 dva) created on screen using Psychtoolbox.

Procedure

The experiment consisted of three test blocks, with 10 practice trials and 108 test trials per block (354 total trials). The three blocks corresponded with the three cue conditions, with the color of positive cues matching the target color, negative cues matching the distractor color, and neutral cues matching none of the objects. All the trials in a given block were of the same cue condition. Importantly, the target and distractor colors were randomly selected on each trial from the set of six colors so subjects could not associate specific colors for respective targets or distractors. The order of the blocks was counterbalanced between participants.

Search arrays consisted of twelve objects placed along the circumference of an imaginary circle (radius 3.8 dva). Replicating Carlisle and Nitka (2019), in 2/3 of trials, the array was separated into two hemifields, with six objects of the target-matching color presented on one side of an imaginary vertical midline and six objects of a distractor color on the other. In the remaining 1/3 of trials, the location of the six target-matching and six distractor objects was randomized across the circular array. The target in each array was an object whose opening was either 90˚ or 180˚ (Figure 1).

On each trial, subjects were first presented with the fixation cross. After a 500ms delay, a color cue briefly (100ms) flashed 1 dva above fixation. Following another 500ms delay, the search array appeared. Subjects were tasked with reporting when they found the target object by pressing the up or down arrow keys, corresponding with the orientation of the target's gap. If they did not respond within 4,000ms they received a timeout message, whereby the next trial started after a 2,000ms delay.

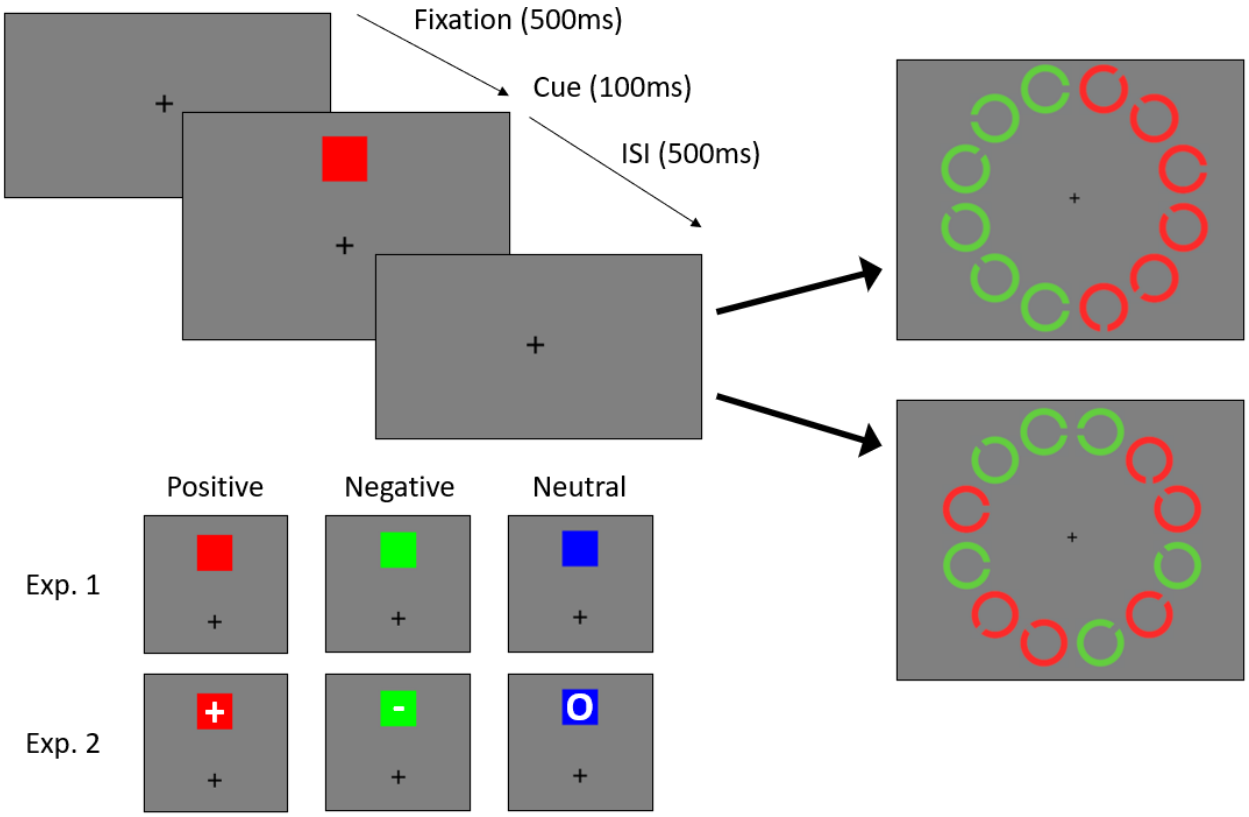


Figure 1. Stimuli and procedure for Exp. 1 and 2. The fixation cross was displayed for 500ms, after which the cue appeared for 100ms. 500ms after the cue disappeared, the search arrays were displayed until response or after 4s. In Exp. 1, separated arrays were randomly presented on 2/3 of trials and intermixed on 1/3, while in Exp. 2 each array type corresponded with the two blocks. In Exp. 2, cues contained a symbol to indicate their use for search.

Experiment 2

Using the same target of seventy-two as in Experiment 1, seventy-five participants were recruited from the same pool. Using the same elimination criteria, three subjects' data were eliminated. The procedure was nearly identical, with a key modification. Instead of organizing cue types by block, cue types were randomized on a trial-by-trial basis. The purpose of this organization is to test if negative template effects exist when subjects are not repeatedly using the same template-building strategy. In order for subjects to know how to use the cue for the upcoming search array, a white symbol was presented inside the cue itself corresponding with each cue type (positive, +; negative, -- ; neutral, O). Subjects completed a practice block of nine trials, with three trials per cue type, followed by 354 test trials.

CHAPTER THREE

RESULTS

Experiment 1

Accuracy

When subjects' accuracy was compared using a repeated-measures ANOVA (Figure 2), there was a significant effect of cue type ($F(2,146) = 11.68$; $p < .001$; $\eta_p^2 = .138$). Subjects were more accurate when given positive cues (M = .97) compared to negative (M = 96; p = .033) and neutral (M = .94; p < .001) cues. Negative cues were also significantly more accurate than neutral cues (p = .015). There was no significant difference between array types ($F(1,73) = 3.00$; $p = .087$; $\eta_p^2 = .039$), nor was there an interaction between conditions ($F(2,146) = .998$; $p = .371$; $\eta_p^2 = .013$).

Reaction Time

To compare RT across the three cue conditions (positive, negative, neutral) while also accounting for array conditions (separated, intermixed), a 3X2 repeated-measures ANOVA was performed (Figure 3). There was a significant main effect of cue type ($F(2,146) = 123.46$; $p < .001$; $\eta_p^2 = .628$), replicating Arita et al. (2012) as well as Carlisle and Nitka (2019). RTs for positive cues (M = 1,356ms) were faster than negative cues (M = 1,605), leaving neutral cues (M = 1,768ms) as the slowest. Unlike Carlisle and Nitka, however, there was a significant effect of array type ($F(2,73) = 7.89$; $p = .006$; $\eta_p^2 = .098$), where RTs in separated arrays (M = 1,562ms) were slightly faster than those in intermixed arrays (M = 1,590ms). The observed mean RT range between ~1,300 and 1,700ms is consistent with previous work using this standard procedure (see Arita et al. 2012; Beck and Hollingworth, 2015; Carlisle and Nitka, 2019).

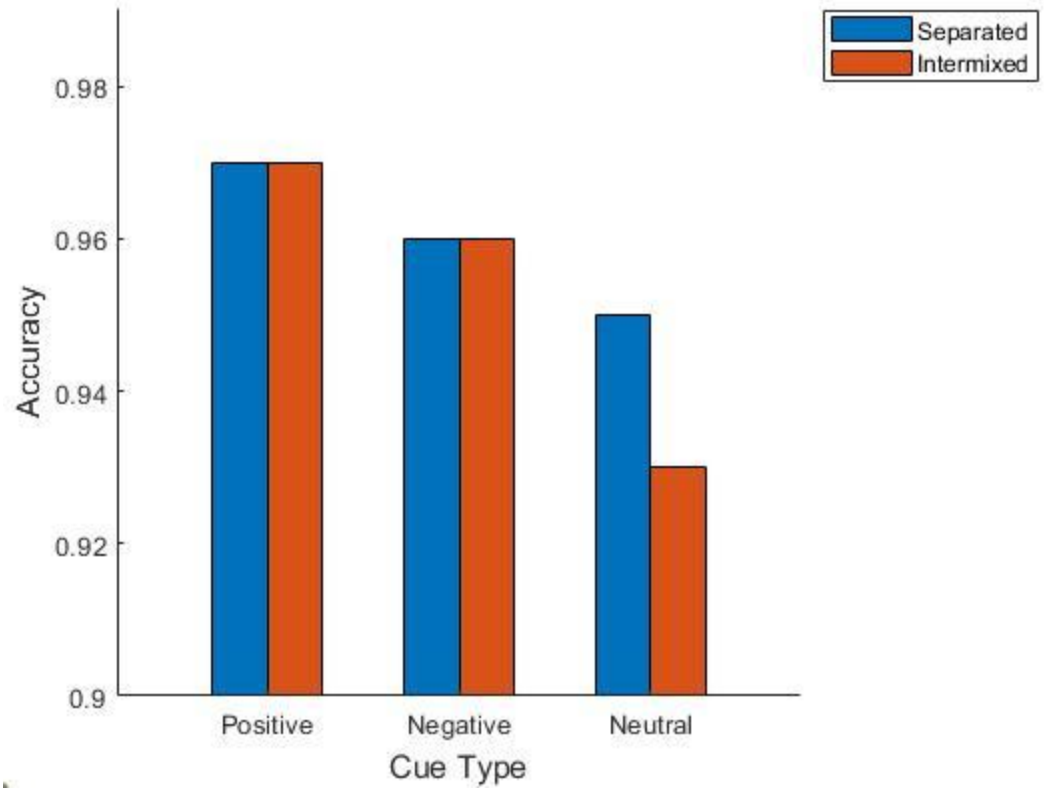


Figure 2. Accuracy percentages in Experiment 1. Subjects were more accurate when given positive cues (M = .97) compared to negative (M = .96) and neutral cues (M = .94), and when given negative compared to neutral cues. There was no significant difference in accuracy between array types (p = .087).

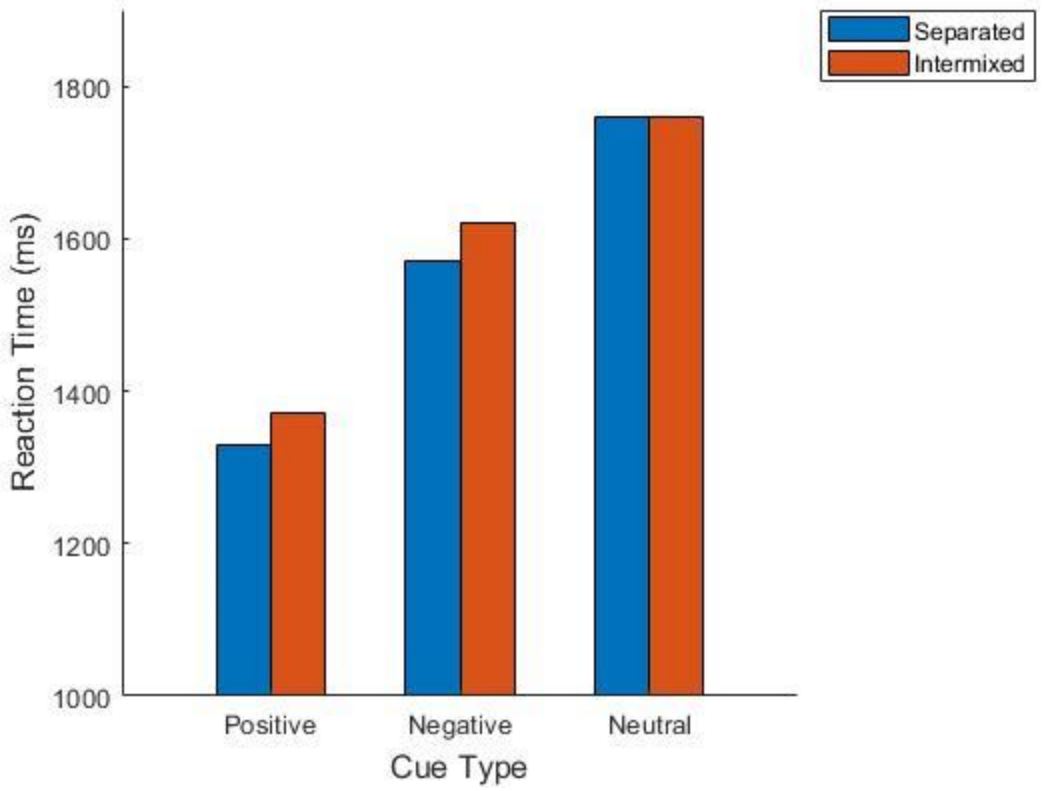


Figure 3. Reaction Time data for Exp. 1. Subjects found targets faster when given positive cues (M = 1,356ms) compared to negative (M = 1,605ms) and neutral (M = 1,768ms) cues. Importantly, negative cues were significantly faster than neutral cues. Similarly, subjects were faster in separated arrays (M = 1,562ms) than in intermixed arrays (M = 1,590ms).

Also unlike Carlisle and Nitka (2019), there was a significant interaction between cue type and array type ($F(2,146) = 3.058$; $p = .050$; $\eta_p^2 = .040$). RT was faster in both positive and negative cues for separated arrays compared with intermixed arrays ($p = .008$; $p = .003$), however there was no difference in RT between array types for neutral cues ($p = .927$).

When splitting blocks into three tertiles as Berggren and Eimer (2020) had done (Figure 4), a 3X3 repeated-measures ANOVA was performed to compare cue condition (positive, negative, neutral) with tertile (first, second, third). Though there was an expected significant effect of cue type ($F(2,148) = 122.80$; $p < .001$; $\eta_p^2 = .624$), in contrast with previous results, there was no effect of tertile ($F(2,148) = 1.049$; $p = .353$; $\eta_p^2 = .014$) nor was there an interaction between the cue type and tertiles ($F(4,296) = 1.271$; $p = .281$; $\eta_p^2 = .017$). Therefore, subjects did not seem to get faster as blocks progressed.

Experiment 2

Accuracy

When comparing subjects' accuracy as in Experiment 1 (Figure 5), there was a significant effect of cue type ($F(2,140) = 24.246$; $p < .001$; $\eta_p^2 = .257$) as well as array type array types ($F(1,70) = 6.897$; $p = .011$; $\eta_p^2 = .09$). Subjects were more accurate when given positive cues ($M = .98$) compared to negative ($M = 97$; $p < .001$) and neutral ($M = .96$; $p < .001$) cues. Negative cues were also significantly more accurate than neutral cues ($p < .001$). Accuracy was higher for separated ($M = .97$) compared to intermixed arrays ($M = .96$). There was no observed interaction ($F(2,140) = .392$; $p = .677$; $\eta_p^2 = .006$).

Reaction Time

As in Experiment 1, the same three cue conditions (positive, negative, neutral) and array conditions (separated, intermixed) were analyzed using a 3X2 repeated-measures ANOVA.

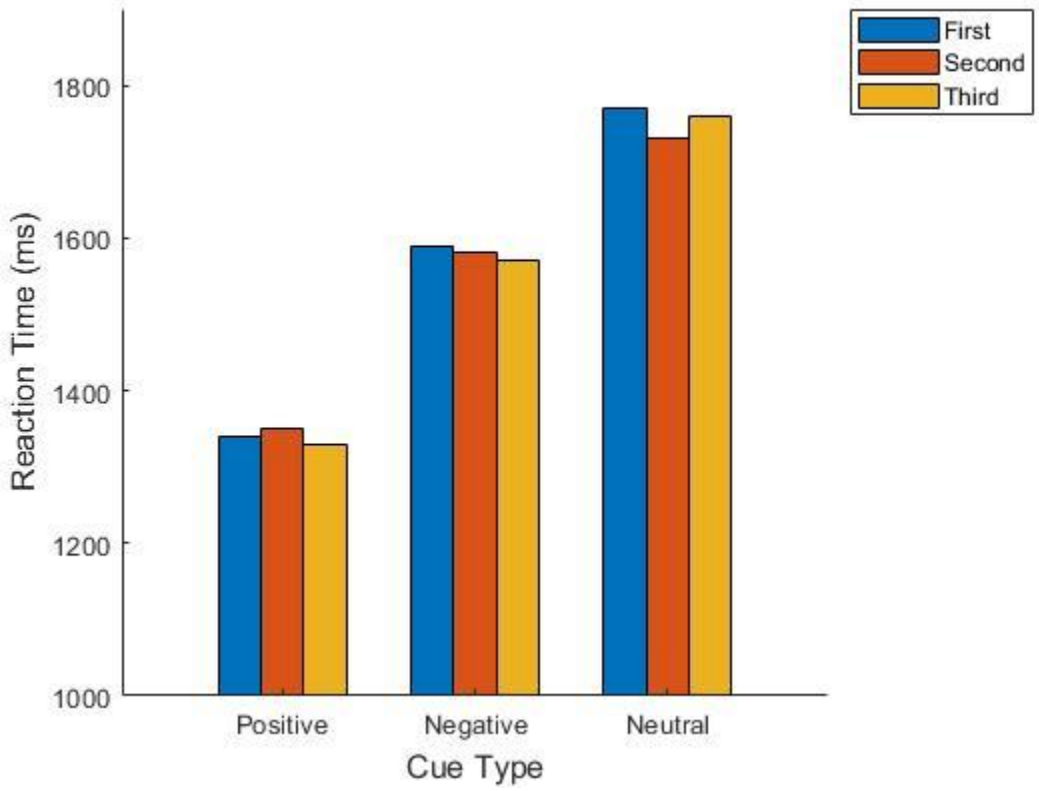


Figure 4. Results from splitting each condition into tertiles. There was no observed effect of tertiles within each condition; that is, subjects did not get faster with more practice with repeated cues of the same type.

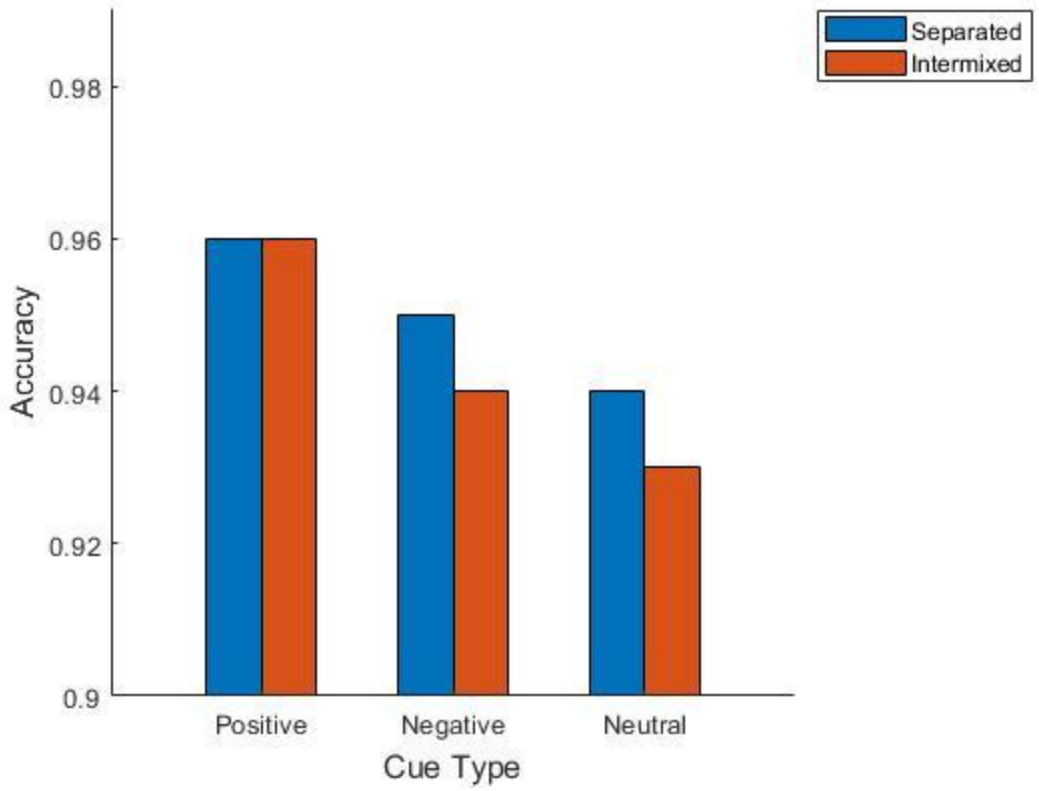


Figure 5. Accuracy percentages in Exp. 2. Subjects were more accurate when given positive cues (M = .98) compared to negative (M = .97) and neutral cues (M = .96), and when given negative compared to neutral cues. Accuracy was higher when given separated arrays (M = .97) compared to intermixed (M = .96).

There was a significant main effect of cue type ($F(2,140) = 196.98$; $p < .001$; $\eta_p^2 = .738$), replicating Arita et al. (2012) as well as Carlisle and Nitka (2019) (Figure 6). RTs for positive cues (M = 1,400ms) were faster than negative cues (M = 1,640), leaving neutral cues (M = 1,765ms) as the slowest. It is important to note that these mean RTs are nearly identical to those in Experiment 1 by mere milliseconds. Again, unlike Carlisle and Nitka, there was a significant effect of array type ($F(2,70) = 8.04$; $p = .006$; $\eta_p^2 = .103$), where RTs in separated arrays (M = 1,576ms) were slightly faster than those in intermixed arrays (M = 1,627ms). Unlike Experiment 1, there was no interaction effect ($F(2,140) = .156$; $p = .856$; $\eta_p^2 = .002$)

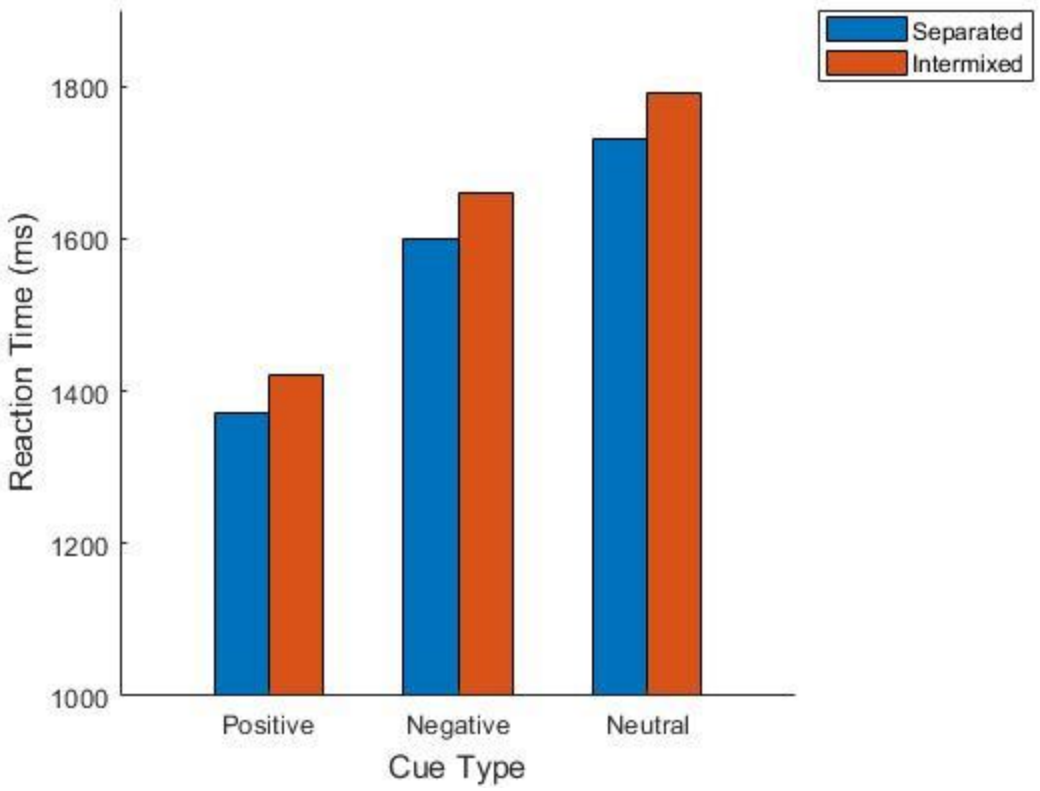


Figure 6. Reaction Time data for Exp 2. Subjects found targets faster when given positive cues (M = 1,400ms) compared to negative (M = 1,640ms) and neutral (1,765ms) cues. Importantly, negative cues were significantly faster than neutral cues. There was no main effect of array type.

CHAPTER FOUR

DISCUSSION

The purpose of this study was to confirm the existence of negative template effects as independent of practice effects and to attempt to reconcile contradicting explanations for the effect (if it indeed exists). While Experiment 1 was a replication of a previous study (Carlisle and Nitka, 2019) that would help in confirming the effect, Experiment 2 introduced a novel manipulation to investigate explanations for the mechanism behind the effect.

Important findings in Experiment 1 included the difference in performance in array conditions as well as the absence of strong practice effects. Carlisle and Nitka (2019) concluded that the spatial locations of the objects in the search arrays were irrelevant to RT, as they had found no effect of array condition. Therefore, using a hemifield design (which would make it easier for subjects to organize objects by location rather than the cued feature) did not influence the use of negative templates. However, results of the present study contradict this conclusion; there was a difference between RTs in hemifield arrays compared to intermixed arrays, where subjects found targets faster in hemifield arrays. This does support the argument put forward by Beck and Hollingworth (2015) that spatial components of search may affect search using negative templates, however it does not necessarily do the same for an argument that negative templates are simply spatially oriented in nature.

With the added analysis of splitting blocks into tertiles to test for practice effects, the results similarly did not replicate those found by Berggren & Eimer (2020). While that study did find a significant reduction in RT costs for negative cues (compared to neutral cues) as experimental blocks progressed, this study did not. Two major differences between this study and Berggren and Eimer (2020) should be noted, however. The present study had fewer trials,

which may dampen the ability to see effects as participants continued with practice. More importantly, array types were randomized throughout each block which would likely interrupt potential habituation, considering subjects had slower performance on intermixed trials. Therefore, this experiment alone may not be sufficient to conclude that negative templates effects are not simply explained by practice effects.

The purpose of Experiment 2 was to attempt the breakup of practice by randomizing cue types on a per-trial basis. With subjects not being able to predict how to use the cue on an upcoming trial, they would likely see slower RT values overall compared to Experiment 1 and potentially little difference in performance between cue types. This was not the case; as pointed to in the *Results* section, the mean RT values were nearly identical across experiments, and further, they were nearly identical respective to each cue type. This finding is remarkable, as it seems subjects use positive and negative templates without predicting the upcoming cue with the same efficiencies respective to a predictable design.

Subjects' use of positive and negative templates in the first experiment seems relatively simple, as they can use the same search strategy on successive trials until they are told not replace that strategy with a new cue type. How might subjects use these templates in the second experiment? One explanation could be that subjects form strategies with the practice blocks given prior to the experiment, linking a specific search strategy with the appearance of one of the cue-use markers (those being the +, -, and O symbols). Whenever one of the symbols would be presented, subjects would retrieve the strategy respective to that specific symbol. A possible investigation of this could be the presentation of cues and search arrays at the same time, giving subjects little time to retrieve the cue strategy from memory.

Based on the evidence from both experiments, this study does not support either account of automatic templates for rejection and search-and-destroy. If templates for rejection were automatically implemented, the mean RTs would be nearly identical between positive and negative cues, as it assumes that distractors are not (or barely) attended to at all. If search was through most or all distractors before moving on to target-matching objects, then there would be RT costs for negative cues compared to neutral. It is clear that neither of these patterns are present in the results of this study. The results of this study seem to support a register-and-destroy account (see Beck et al., 2018, and Berggren & Eimer, 2020), where there is initial capture by distractors before attention is guided to target-matching objects. This initial capture is implicated in the distance of negative cue RT means set between both positive and neutral means, as it takes a few hundredths of a millisecond to move on from that initial capture.

In conclusion, the results of both experiments replicated the cue effects of Carlisle and Nitka (2019), but here it is argued these findings support the register-and-destroy account, rather than the automatic rejection account. The array effects, however, did not replicate; this lends support to the feature/location-based recoding accounts. And finally, splitting blocks by tertile in Exp. 1 along with the results of Exp. 2 reject the hypothesis that negative templates are analogous to practice effects.

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VITA

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