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Exploring the Relationship between Long-Term Memory and Attention through Attentional Templates

Rebecca Rose Goldstein
Louisiana State University and Agricultural and Mechanical College

EXPLORING THE RELATIONSHIP BETWEEN LONG-TERM MEMORY AND ATTENTION THROUGH ATTENTIONAL TEMPLATES

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Rebecca Rose Goldstein
B.A., Washington College, 2006
M.S., Villanova University, 2008
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Dedicated to

Warner "Joseph" Delaune III

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ABSTRACT

It is assumed that the contents of visual working memory (VWM) guide attention. This notion has been challenged by work which has demonstrated that multiple searches for the same target changes contralateral delay activity (CDA), an event-related potential that is the putative marker of the amount of information maintained in VWM. It has been suggested that the disappearance of the CDA with an invariable target marks the transfer of the attentional template from VWM storage to long-term memory (LTM) storage. Therefore, LTM may guide attention in many situations where it has previously been assumed that VWM guides attention. However, while the transfer of attentional template from VWM to LTM is demonstrated through a decrease in the amplitude of the CDA, this shift has not been accompanied by a corresponding behavioral change in response times. The purpose of the present study was to test the hypothesis that a LTM template leads to faster performance than a VWM template (*the LTM template hypothesis*). Two experiments were conducted to explore this hypothesis. In Experiment 1, the LTM template hypothesis was examined by comparing performance between two different groups of subjects: the first group searched for a target that changed on every trial (variable) while the second group searched for a target that was invariable across trials. In Experiment 2, one group of subjects searched for both the variable and invariable targets. The results showed that a LTM template (invariable target search) leads to faster performance than a VWM template (variable target search). Roughly six times as many trials were required for an effect on performance compared to the number of trials required for an effect in CDA amplitude. Eye tracking results suggest the change in performance is due to more efficient search initiation and target verification.

CHAPTER 1. INTRODUCTION

Many everyday tasks, such as searching for an icon on your smartphone, involve visual attention. Visual attention is the act of selecting some information for processing at the expense of other information in the environment. This selection process is guided by information that is stored in memory about the search task goals. Imagine you are playing a new game on your phone in which you must search for an elf in varying complex and cluttered holiday scenes. This elf is dressed in a little blue suit, has jet black hair, and a curly mustache. Each of these elements is a feature that can be used to select elf-consistent information in the scene (black or blue information in the scene) for further processing. Initially, these features of the elf are hard to remember. To aid your memory for the elf, you repeatedly look to the sidebar in the game that contains an image of the elf as a cue for your search target. As you progress through the scenes of the game, you start to reference the sidebar only once for each scene, because you are capable of holding the image of the elf in your visual working memory (VWM) for the length of the scenes. The game has hundreds of scenes and you are always searching for the same elf. Eventually, the sidebar with the picture gets only a periodic glance while playing the game because the image of the elf has been stored in long-term memory (LTM). This example illustrates how VWM can be used to maintain a representation of the search target over the short run, but with repetition, LTM may play a larger role in this maintenance.

Depending on the consistency of the search target, different memory representations may influence the selection process involved in visual attention. In the example above, the same elf is the target of every search (invariable target), allowing a LTM representation to be established. However, if there is a different elf to search for in each scene (variable target), a new representation of the elf would need to be formed in VWM for each trial. Therefore, depending on the type of target (variable or invariable), search may be guided via a VWM representation or a LTM representation. While there is a long history of research showing that VWM can be used to guide attention during search, recent research has examined whether LTM can be used to guide attention. However, the transition from VWM to LTM guidance has been tracked predominately by investigating the presence or absence of neural markers of VWM, and the ability to use LTM for guidance without first engaging VWM is not well established. The purpose of the proposed study is to investigate the question of how VWM attentional guidance and LTM attentional guidance may differ by investigating the impact of each type of guidance on eye movements.

1.1 VISUAL ATTENTION AND VISUAL SEARCH

Visual attention is the process that allows humans to handle the influx of information that is available in the visual world at any given moment. For example, returning to the smart phone game mentioned earlier, each holiday scene where the elf is hidden can be very complex and cluttered, containing too much information to process at any one time, so one must instead select a subset for processing. Visual attention is the mechanism that allows for this subset selection while excluding the rest of the scene. This selection requires criteria to determine the information that will be processed further and/or the information that will be inhibited. Once the criteria for selection have been set, the selected information receives further processing that leads to awareness of the visual information (Belopolsky, Kramer, & Theeuwes, 2008; Posner, 1994). Searching for a target, as in the elf game, is one example of the use of visual attention: An item must be attended to determine its identity (e.g. 'this is a dreidel'), then a decision has to be made about that item (e.g. 'this is not what I am looking for'), then attention must be shifted to the next item for processing, until the target is found. Visual search is an ideal method of studying the process of attention because it is an everyday task that generally requires selective visual attention, and the variables in a visual search task that generally affect visual attention are easy to modify for study in the lab.

A typical visual search task begins with the presentation of the target (the target cue), which is the focus of the search task (e.g., a Landolt square, see Figure 1). Following the target cue, the search array is presented containing distractors (non-target items) in addition to the target (Figure 2). Search arrays can range from very simple, with individual items arranged in various configurations called stimulus arrays (e.g., a scene of rotated 'T's and 'L's), to very complex (e.g., a photograph of a real-world scene). While real-world scenes have the benefit of high ecological validity, stimulus arrays allow for easy manipulation of factors known to affect visual attention (e.g., set size or the number of items in the search array, including the target). Participants search the array until they make a decision regarding the target, such as whether the target is present (or absent) or whether the target exhibits a particular feature (e.g., oriented to the right or left).

Figure 1. Landolt square is on the left and Landolt circle is on the right.

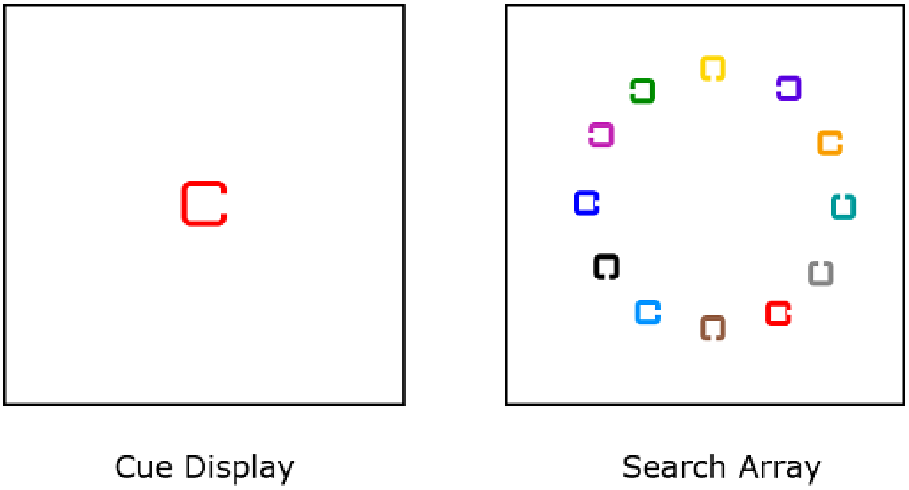

Figure 2. An example of a visual search task with a target cue display before the search array.

The efficiency of selective attention is generally assessed in the visual search task by measuring response time (RT) or search slope. RT is the amount of time from when the search array is presented until a response is given, typically for accurate trials only. RT is typically used as an estimate of how quickly attention is guided to the target, although other variables can also play a role in RT. If set size is varied, the RT can be plotted against set size; the slope of this function is used as an estimate of how much time is needed to attend to each additional distractor in the search array. These dependent variables (RT and search slope) are expected to vary as stimulus characteristics that affect visual attention are manipulated in the search arrays. For example, when distractors are very different from the target (e.g., a red target among green distractors), the search slope is shallower than when distractors are very similar to the target (e.g., a red target among pink and orange distractors). A shallow search slope shows that adding distractors does not add a lot of time to the search, indicating a more efficient search.

Although RT is a common measure of attention in visual search, its use is not necessarily sufficient for understanding the process of attentional selection or guidance, because RT is composed of several different processes. The first component of RT is called search initiation. This refers to the amount of time it takes to start the search process (i.e., move the eyes) once the search array appears (Malcolm & Henderson, 2009, 2010). The second component of RT is called navigation. This refers to the period of time when the target is being looked for actively (Castelhano, Pollastek, & Cave, 2008; Malcolm & Henderson, 2009, 2010). The third component of RT is called verification. This refers to the process of target recognition and decision making (Castelhano et al., 2008; Malcolm & Henderson, 2009, 2010). The current study examines eye movement behavior during all the stages comprising total RT because the stages may be impacted by memory representations differently.

Guidance has typically been assessed in two ways. The first is through the search slope (Treisman & Gelade, 1980; Wolfe, 1994), which provides the processing speed of the stimuli in the search array. A second, more direct method, is to use eye movements, which include fixations, the periods of time when the eye considered to be paused in a given location, and saccades, the eye movements between fixations. Using eye movements to measure guidance, while varying parameters of the search task, can allow for testing hypothesizes about the variables that affect selective attention during visual search. Eye movements provide a direct method of isolating the search initiation and navigation periods by using particular eye movements to mark the beginning and ending of each period. For example, the period of navigation is defined as from the first saccade on the search array until the first fixation on the target. Efficient search would be characterized by shorter fixation durations and fewer fixations during the period of navigation. Therefore, eye movements are an ideal method to test hypotheses about how visual attention is altered by external factors, such as target-distractor similarity, or internal factors, such as VWM and LTM representations. In addition, examining the distractors and distractor features fixated during navigation can lend insight into what specific information is being used to guide attention (Castelhano & Heaven, 2011; Liversedge & Findlay, 2000; Zelinsky, 1996). The purpose of the current study was to examine search initiation, navigation, and verification in order to assess how different memory representations impact guidance of attention.

1.2 GUIDING ATTENTION IN VISUAL SEARCH

The guidance of attention toward a target has been proposed to be controlled by a memory representation of the target (Bundesen, 1990; Desimone & Duncan, 1995; Duncan & Humphreys, 1989; Treisman & Gelade, 1980; Wolfe, 1994; 2007). Typically, it is assumed the mental representation guides attention from VWM (Desimone & Duncan, 1995; Duncan & Humphreys, 1989). However, depending on the situation, guidance by a memory representation may be performed from VWM or LTM (Bundesen, Habekost, & Kyllingsbæk, 2011; Woodman, Luck, & Schall, 2007; Woodman, Vogel, & Luck, 2001). VWM is a capacity limited store (Luck & Vogel, 1997) in which contents are actively manipulated to complete tasks. Furthermore, this active maintenance allows for the contents in VWM to be accessible (Woodman, Vogel, & Luck, 2012). LTM is a capacity unlimited store (Standing, 1973; Standing, Conezio, & Haber, 1970) that can involve automatic processing of its contents to complete tasks (Logan, 1988). The unlimited capacity allows for the contents in LTM to be durable, however, the accessibility of these contents remains unclear. Therefore, there are likely differences in how attention is guided by a mental representation stored in VWM versus LTM.

1.2.1 VISUAL WORKING MEMORY GUIDANCE. There is ample evidence to suggest that a mental representation held in VWM is capable of biasing the allocation of attention (Carlisle, Arita, Pardo, & Woodman, 2011; Carlisle & Woodman, 2011ab, 2013; Kumar, Soto, & Humphreys, 2009; Malcolm & Henderson, 2009; Olivers, Meijer, & Theeuwes, 2006; Schmidt, MacNamara, Proudfit, & Zelinsky, 2014; Schmidt & Zelinsky, 2011; Soto, Heinke, Humphreys, & Blanco, 2005; Soto, Hodsoll, Rotshtein, & Humphreys, 2008; Soto, Humphreys, & Heinke, 2006; Soto, Humphreys, & Rotshtein, 2007; van Moorselaar, Theeuwes, & Olivers, 2014; Woodman & Arita, 2011). Two functions have been attributed to this mental representation: (1) it aids in biasing attention to similar features in the visual field and (2) it is a reference to compare potential targets against (Bravo & Farid, 2009, 2012, 2014; Duncan & Humphreys, 1989). The first function is utilized during navigation in the process of guidance. The second function is utilized during verification in the process of response selection. (See Eimer, 2014, for a detailed account of the components of visual search as continuous phases and not distinct stages.)

Several studies have shown that the contents of VWM can guide attention toward similar items in the visual search array (Kumar, et al., 2009; Soto, et al., 2005; Soto, et al., 2008; Soto, et al., 2006; Soto, et al., 2007). For example, in one study participants were required to complete two concurrent tasks: retaining information in VWM for a later memory test while performing visual search. The authors had participants hold a shape in memory while searching for oriented bars inside shape outlines. The presence of the VWM shape in the search array resulted in slower RTs when the VWM shape surrounded a distractor, but aided RTs when it surrounded the target. This suggests that the memory matching item guided attention to the shape in the search array (Soto et al., 2005). In addition, eye movements revealed the same pattern, more first saccades were made towards the distractors that matched elements of the memory item. The authors concluded that the contents of VWM can guide attention toward features in the search array that are consistent with features stored in VWM (Soto et al., 2005).

Furthermore, neural markers of VWM are present in visual search tasks, indicating that VWM is engaged during search. Specifically, contralateral-delay activity (CDA) is an event-related potential (ERP) recorded at posterior electrode sites and takes advantage of the lateralized processing of visual information that occurs in the brain by measuring the difference in activity between hemispheres contralateral and ipsilateral to the attended stimulus (Figure 3). The CDA appears 300 ms after the onset of the stimulus and is sustained during VWM retention (Vogel & Machizawa, 2004). The CDA increases with set size until capacity limits are reached, at which point it plateaus, making it an ideal marker of the number of items retained in VWM. Carlisle, Arita, Pardo, and Woodman (2011) found that the CDA is present following the presentation of the target cue (Figure 4); furthermore, the CDA was greater in amplitude when participants searched for two targets than when they searched for one target, suggesting that an attentional template stored in VWM is used to guide visual search.

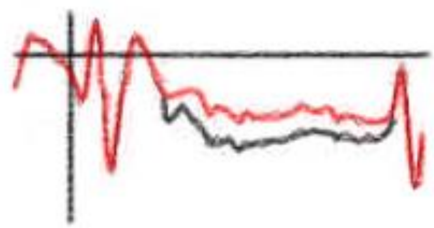

Figure 3. The black line represents the activity contralateral to the stimuli presentation and the red line represents the activity ipsilateral to the stimuli presentation. The space between the two lines or their difference is the CDA.

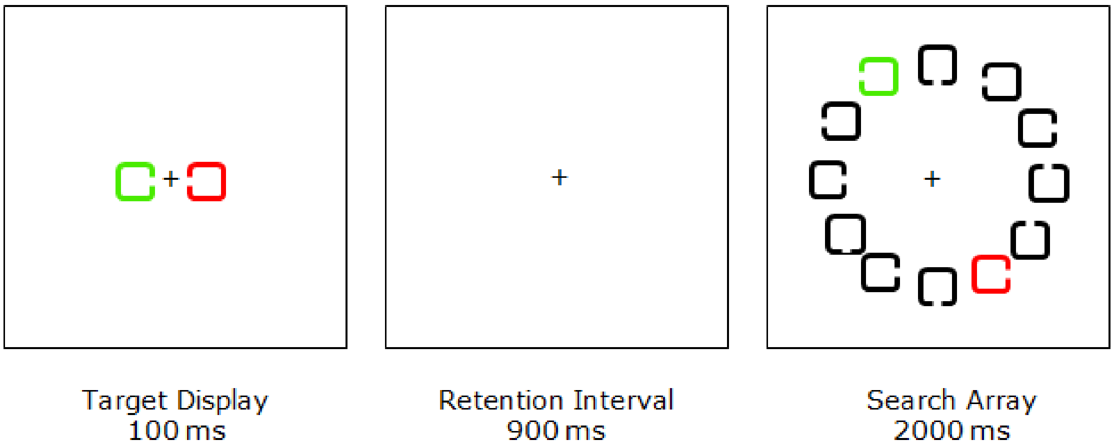

Figure 4. Adapted from Carlisle et al. (2011), the trial procedure for a one target trial used to assess where attentional templates are stored. The target display contained two cues and participants were informed prior to the start of the block which color to attend to as the target. The objective is to indicate whether the target is present or absent in the search array. The appearance of the CDA during the 900 ms retention interval is used as evidence that the previously presented target cue is stored in VWM.

1.2.2 LONG-TERM MEMORY GUIDANCE. A mental representation held in LTM also biases the allocation of attention (Carlisle et al., 2011; Gunseli, Olivers, & Meeter, 2014; Woodman, Luck, & Schall, 2007; Woodman, Vogel, & Luck, 2001). The mental representation should theoretically provide the same two services as a VWM representation: (1) a LTM template should aid in the biasing of attention to similar features in the visual filed during guidance and (2) a LTM template should be used as a reference to compare potential targets against during verification in response selection.

Woodman, Vogel, and Luck (2001) used a dual task design (participants searched for a target while also maintaining another item in VWM) in which the memory item changed from trial to trial, but the target for the search array was invariable. Regardless of whether participants completed the search task alone, or the dual task, the search slope was the same; only the intercept differed. The authors concluded that the additional contents of VWM in the dual task condition did not disrupt guidance during visual search (because search slope was the same), but the items in VWM impacted either search initiation or verification because there were differences in intercepts. However, given the evidence that VWM guides visual search (Kumar, et al., 2009; Soto, et al., 2005), it might seem surprising that there was no difference in search slopes between the search alone and dual task conditions. Woodman and colleagues proposed that the VWM load did not affect guidance because searching for the same target on every trial may have led to use of a template stored in LTM.

To directly probe the use of LTM templates to guide attention, Woodman, Luck and Schall (2007) used the same dual task procedure as Woodman et al. (2001), but the target was either invariable for the entire experiment or the identity of the target changed from trial to trial. When the target was invariable, search slopes were similar with and without a VWM load of four items. However, when the search target was variable, the visual search task produced steeper search slopes when there was a VWM load. Woodman et al. (2007) concluded that in the variable target condition, the VWM load interfered with performance because the template was also being held in VWM, on the other hand, there was no inference in the invariable target condition because the template was maintained in LTM.

Furthermore, the CDA has been shown to represent the maintenance of an attentional template in VWM. The CDA has been shown to disappear when the search target is invariable from trial to trial, indicating a shift of the template from VWM to LTM (Carlisle et al., 2011). In a repetition run (i.e. a block of invariable target search trials), the CDA amplitude was found to differ from zero for the first trial through the fourth trial. By trials five, six, and seven the CDA amplitude did not differ from zero (Carlisle et al., 2011; also see Gunseli, et al., 2014; Reinhart, et al., 2014). This finding has been replicated when accounting for hemisphere effects due to the lateralized design (Reinhart, et al., 2014) and for task difficulty (Gunseli, et al., 2014). Carlisle et al. (2011) proposed that the disappearance of the CDA signals the passing of the attentional template from VWM to LTM.

Although there is evidence to support the role of LTM when targets are invariable, there currently is no consensus on whether the attentional template can guide attention from LTM, independent of VWM, and what accompanying behavioral markers distinguish LTM attentional guidance from VWM attentional guidance. Evidence supporting the passing of an attentional template from VWM to LTM is based primarily on research with ERPs (Carlisle et al., 2011; Gunseli et al., 2014; Reinhart et al., 2014) and assumptions based on search slopes (Woodman et al., 2007; Woodman et al., 2001). Although, the change in the CDA across trials is accompanied by a significant decrease in RTs, Carlisle et al. (2011) did not find a difference between invariable and variable target RTs. Thus, it is unclear what component of search (i.e., search initiation, navigation, or verification) is benefitting from the repetition of the target. In ERP experimental designs, search arrays are designed to take advantage of the lateralization of the CDA, and eye movements are restricted. The current study is designed to use eye movements to investigate the differences between guidance from a VWM attentional template versus a LTM attentional template.

CHAPTER 2. EXPERIMENT 1: DISENTANGLING VWM AND LTM GUIDANCE

New evidence suggests LTM attentional guidance occurs in situations previously thought to exhibit VWM attentional guidance, yet there currently is no consensus on if or how LTM attentional guidance is different than VWM attentional guidance. Accessing information from LTM is considered to be effortful whereas the contents in VWM are considered to be in the forefront of consciousness (Cowan, 2005). This suggests VWM attentional guidance would be beneficial compared to LTM attentional guidance. On the other hand, LTM is associated with better performance on a task each time the task is performed and learning occurs (Lassaline & Logan, 1993). Based upon the ERP studies there appears to be no difference in the attentional guidance provided by VWM and LTM (Carlisle et al., 2011; Gunseli et al., 2014). However, RT, search slope, and CDA are limited measures of guidance because they indirectly assess guidance. RT is insufficient to distinguish between search initiation, navigation, or verification. In addition, search arrays used in ERP experiments are designed to rely on covert shifts of attention, without eye movements. Visual search tasks completed with covert shifts of attention limit the behavioral responses used to assess performance to RTs. The current study investigated whether VWM attentional guidance and LTM attentional guidance differ in a visual search task that requires eye movements.

The transition from using a VWM template to using a LTM template may be understood within the parameters of *Instance theory* (Logan, 1988). A LTM attentional template is indexed by a decrease in the CDA amplitude (Carlisle et al., 2011; Gunseli et al., 2014; Reinhart et al, 2014). The pattern produced by the decrease in CDA across time matches the power law function where there is a dramatic change before a leveling off (Carlisle et al., 2011; Newell & Rosenbloom, 1981; Reinhart et al., 2014; Shiffrin & Schneider, 1977). Instance theory (Logan, 1988) explains this change in the slope of the function as a shift from using an algorithm to complete the task to using memory. The algorithm is a general process that has a set stopping point regardless of the task. Memory searches for a prior instance of that task and, once retrieved, the instance is used to complete the task. An event may contain more information than is required to aid in completion of the task later, thus an instance represents the specific information necessary to complete the task (Lassaline & Logan, 1993). The more prior instances (episodes) in memory the quicker the task can be completed. As the instances increase, memory is able to reach a solution before the algorithm. The role of VWM can be seen as the initial use of the algorithm and the role of LTM can be seen as the use of memory (Anderson, 1982; Logan, 1988). The decline and eventual disappearance in CDA across initial trials with an invariable target reflects practice and the transition to using LTM to complete the visual search task.

With repetition of the invariable target on the target cue screen, the absence of the CDA amplitude suggests the invariable target is stored in LTM and that a prior instance with the invariable target has been retrieved. However, the appearance of the search array may also result in an instance retrieval. A different instance might be required to perform the visual search task because the separation of the target cue screen and search array could represent different events. An instance contains the information necessary to complete the task, the appearance of the search array may result in the retrieval of an instance that contains more information than the instance retrieved on the cue screen. The instance could contain information about distractors in addition to the target. In Carlisle et al. (2011) the targets had a pop out effect being one of only two colored items in the array compared to the black distractors. This may have prevented any benefit of being able to use a prior instance to complete the task because the pop out would have resulted in fast automatic search. This would suggest the change in CDA amplitude on the cue array reflected faster recognition of the target on the trial, but not necessarily reflect the instance utilized on the search array. This would support the absence of an RT effect between invariable and variable targets in the previous ERP studies (Carlisle et al., 2011).

Alternatively, a difference between VWM and LTM attentional guidance could exist if the cue screen and search array form one event that utilizes the same instance to complete the task. The possible benefit that LTM storage has over VWM storage could be due to how guidance is formed. Guidance does not happen instantaneously. Evidence has shown that guidance takes time to be initiated with a minimum of 200 milliseconds (ms) to be optimal depending on the target cue (Schmidt & Zelinsky, 2011; Vickery, et al., 2005; Wolfe, et al., 2004). An instance that can be retrieved faster than the algorithm could lead to faster establishment of guidance. The time needed to establish an attentional template may reflect the time needed to create the attentional template in VWM. This process could lead to slower initiation of the first saccade during search or looking at more distractors before the target. Search would be inefficient because the focus provided by guidance is not yet established. However, if given enough time between the target cue and the search array this benefit would be washed out due to the algorithm having enough time to reach its stopping point. The failure to find differences in the RT for variable and invariable targets may be the result of the experimental design required to measure the CDA obscuring differences in VWM and LTM attentional guidance.

Experiments designed to observe the CDA provided adequate time for guidance to be fully established before the search array appears. In all of the previously discussed ERP studies (Carlisle et al., 2011; Gunseli et al., 2014; Reinhart, et al., 2014) the target cue screen is followed by a 900 ms blank interval. This interval is to ensure the CDA that appears 300 to 1000 ms after the stimulus onset is occurring due to the presented target cue, not the following search array. A 900 ms delay is long enough for a picture cue and a word cue to produce an efficient search template (Schmidt & Zelinsky, 2011; Vickery, et al., 2005; Wolfe, et al., 2004). The current study investigated differences in VWM attentional guidance and LTM attentional guidance by manipulating the inter-stimulus interval (ISI) between the target cue and search array.

Additional elements of the previously discussed ERP studies may have prevented finding differences in VWM and LTM guidance. First, the color of the target was provided prior to each block (Carlisle et al., 2011). Thus, the cue screen provided information about the gap location in the Landolt target and not the target color. To complete the task, the participant had to locate the color in the search array and then make a decision regarding whether the target was present based on the gap location. The gap location determined whether the target was invariable not the color. Second, the search arrays consisted of two items in color among 12 black distractors. The search size was closer to two than twelve, because the colors stood out, it is likely the gap was not used to guide attention. Carlisle et al. did not find a different in performance between a VWM and LTM template. The experimental design and use of RT may have prevented finding a difference in guidance and/or verification. Third, the lack of the difference could be a result of the 900 ms interval creating a situation where the VWM template is the same as the LTM template for search initiation and/or guidance and/or verification.

Finally, the repetition lasted no longer than seven trials (Carlisle et al., 2011; Gunseli et al., 2014). The RT difference may require more time to emerge compared to the change in CDA. The current study investigated LTM guidance by directly manipulating the need to use guidance to find the target and by increasing the number of trials to see if RT effects appear later than changes in the CDA.

Experiment 1 was designed to increase the use of guidance as a way to investigate possible differences in VWM and LTM template guidance. Therefore, in Experiment 1, blocks of invariable targets and blocks of variable targets were used to test the LTM template hypothesis. The LTM template hypothesis states a LTM template leads to faster search performance. Typically, the neural marker of LTM guidance is found within three trials and is strong by seven trials with an invariable target (Carlisle et al., 2011; Gunseli et al., 2014; Reinhart et al., 2014). Thus in Experiment 1, the length of each run was 30 trials and the trials within each run were broken into 5 6-trial bins. It is expected that faster guidance will appear later in the eye measures compared to neural findings and performance will fit the power law function for the invariable target (a steep change followed by a leveling off). However, this is based on the assumption that the change in RT mirrors the CDA change and that the change in both measures reflects more efficient guidance. Since RT is not a sensitive measure of guidance, it is unclear whether differences in LTM and VWM performance are due to guidance and/or verification. The decision task was a judgment regarding the gap position. Therefore, color, the feature of the LTM template, could be used to guide attention to the target, but color and gap location was needed to make the target decision.

2.1 METHOD

2.1.1 PARTICIPANTS. One hundred and thirty participants were recruited from the Louisiana State University Psychology pool and received course credit for their participation. Analysis included 128 participants (100 female, average age = 19.39) after two participants were replaced for performing at or below chance (50%). All participants reported normal color vision and normal or corrected to normal vision expect for three participants whom normal or corrected to normal vision was missing. Thirty-two participants participated in each of the conditions.

2.1.2 POWER. In order to determine the number of participants needed to find a difference between target type at bin 10, a power analysis was conducted. Cohen's *d* for a dependent samples *t*-test was calculated using the data in experiment one of Chun and Jiang (1998). This study was used because the data had the difference we would predict if LTM produces faster guidance than VWM. In Chun and Jiang (1998), participants searched for a T among Ls. Configurations were old (distractors in the same locations) if the configuration appeared once per block. New configurations were seen once and never again for the rest of the experiment. A dependent samples t-test at epoch 6 (5 blocks equal one epoch) between new and old contexts found old to be significantly faster. Using the sample size, standard error, and means, I calculated a Cohen's *d*, for a dependent samples *t*-test, of 0.47 for the difference, which is approaching a medium effect. The effect size of 0.47 was entered in G*Power 3.1.7 for an independent samples *t*-test. The results of this analysis called for 73 participants per group. On the one hand, this large *N* is reasonable going from a dependent to an independent sample, however, the *N* is rather large compared to previous work. For this reason, I decided to set the *N* to 32 per group and once each group has 16 participants to calculate the effect size for the current experiment. Prior to determining the effect size with 16 participants per group, it was decided to collapse the number of bins to 5 instead of 10. Cohen's *d* for an independent samples *t*-test was calculated for target type (invariable, variable) at bin 5. The calculated Cohen's *d* was 0.54 which is a medium effect. The results of analysis using G*Power called for 44 participants per group assuming a power of .80. In the present study the comparison of interest is target type at bin 5 and collapsing across ISI to make this comparison would create 64 participants in each group. For this reason, I kept the number of participants needed in each group at 32.

2.1.3 APPARATUS AND STIMULI. An Acer computer controlled the timing of events and a Dell computer controlled responses. Stimuli were presented by a 24 inch Benq monitor with a resolution of 1920 x 1080 pixels. The distance between the chin rest and the monitor was 93 cm. An EyeLink 1000 Plus tracker (SR Research LTD, Canada) was used to detect eye movements. The dominant eye of each participant was tracked throughout the experiment. To determine the dominant eye, participants were positioned across from a black dot on the wall and asked to close one eye at a time while looking through the provided card with a hole. When the black dot stayed in view while the other eye is closed was determined to be the dominant eye.

Stimulus displays consisted of Landolt or outline squares (see Figure 1). The squares maintained a visual angle of 0.33° x 0.33° with a line thickness of 0.1° (Beck, Hollingworth, & Luck, 2012). Each display contained 12 squares in a circular design with 11 of the squares being distractors. All of the squares contained gaps (0.07°) located on the left or right. Squares appeared in one of 14 possible colors (blue [RGB 0, 0, 225], light blue [RGB 0, 90, 255], brown [RGB 150, 98, 72], brown/red [165, 42, 42], grey [RGB 138, 138, 138], dark grey [RGB 70, 70, 700], green [RGB 0, 144, 0], olive green [RGB 114, 143,0], orange [RGB 250, 162, 0], pink [RGB 244, 0, 163], purple [RGB 97, 5, 226], red [RGB 255, 0, 0], red/orange [RGB 254, 110, 13], turquoise [RGB 0, 206, 209]).

2.1.4 DESIGN. The experiment was 2 x 2 x 5 mixed model. The between subjects factors were target type (invariable vs variable) and ISI (50 ms vs 900 ms). The within subjects factor was bin (within each block of 30 trials, there will be 5 bins of 6 trials each).

Several dependent measures were examined on the accurate trials when the target was fixated. RT was examined and was broken into three time periods using ocular measures. The period of search initiation was defined by the duration of the first fixation on the display. Navigation was defined as the period from the first saccade on the search array until the first fixation on the target. During navigation the following ocular measures were examined: number of first saccades to the target, number of distractors fixated, and the average fixation duration on the distractors. Verification was defined as the period from the first fixation on the target until the participant's response.

2.1.5 PROCEDURE. Participants provided informed consent prior to starting the experiment. Instructions were presented on the screen and read aloud to the participant. Participants were told they would be presented with an outlined color square followed by a short delay and their objective was to find the color square on the search screen. Participants were instructed to indicate the location of the gap in the square (left or right) by button press once the square was found. Following instructions, participants went through a calibration and validation process to set-up the eye tracker. The eye tracker was recalibrated between blocks. In both the invariable and variable target conditions, participants completed two practice trials and 240 trials broken into eight blocks of 30 trials.

Each trial started with a drift check dot followed by a target cue screen for 200 ms. The cue screen was followed by either a 50 or 900 ms ISI screen (depending on condition). The target cue screen contained an outlined color square representing the target (Figure 5). The search array contained 12 items presented in a circle and randomly placed in the locations in which digits appear on a clock face. Eleven of the squares were

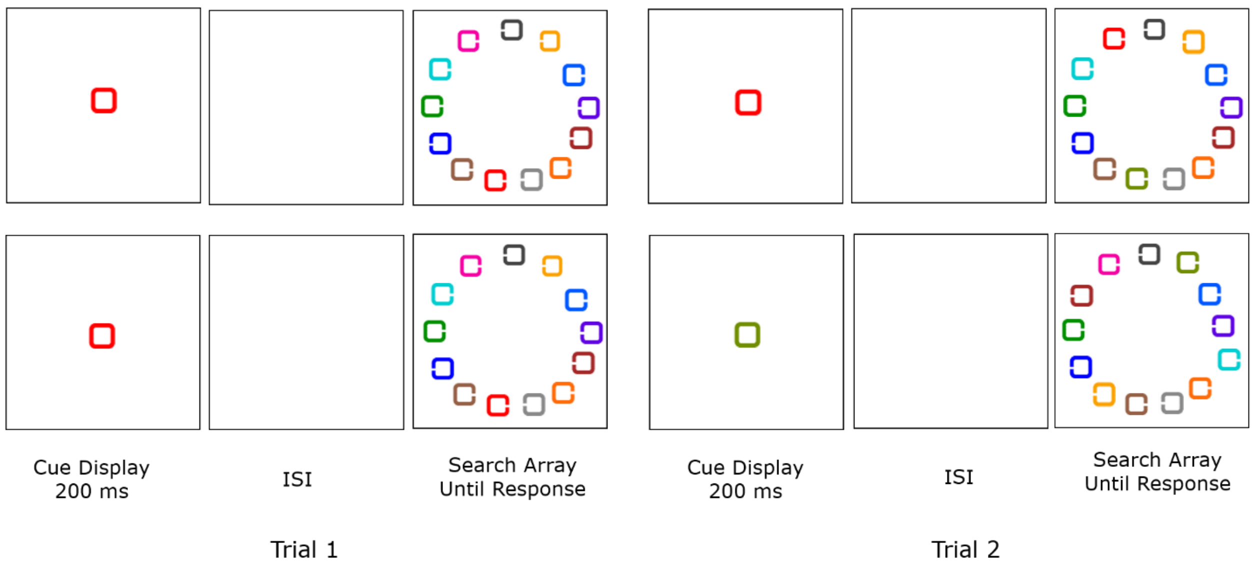

Figure 5. The top line represents the trial sequence for the invariable target condition. On every trial the target was the color red while the gap position and target location changes. In the following block the target was a different color than red and red did not appear as a distractor. The bottom line represents the trial sequence for the variable target condition. In trial 1 the target was red and in trial 2 the target was olive green. In addition, red was not a distractor in trial 2 because it was the target on the previous trial. The length of the ISI was either 50 or 900 ms throughout the entire experiment.

distractors with a unique color and a gap position and the 12th square was the target with a specific color and contained either a right or left gap location. The search array appeared on the screen until the participant indicated the location of the gap in the target by button press.

The invariable target and variable target conditions followed the same procedure except for the following differences. In the invariable target condition, the color of the target remained the same on all 30 trials in a block. Only the location of the gap in the target varied from trial to trial within a block. A new target color was randomly chosen without replacement for each block. In addition, the n-1 block's target color did not appear as a distractor in the n block. In the variable target condition, the target color was randomly selected on every trial. The target color on trial n did not appear as a target or a distractor on a trial n+1.

2.2 RESULTS

Performance was very good with an overall accuracy of 96% (invariable/50 ms = 96%, invariable/900 ms = 98%, variable/50 ms = 96%, and variable/900 ms = 95%). Trials were excluded for inaccurate responses, RT more than three standard deviations above or below the mean, and when the target was not fixated. (Fixating the target was defined by a fixation that fell within the circular interest area sustaining 2.5° of visual angle surrounding the target.) Overall, 7.78% of trials were excluded. The following percentages of trials were excluded for each of the exclusion criteria: inaccurate responses (2.22%), RT (1.48%), and not fixating the target (2.34%). The following percentages of trials were excluded for meeting two of the exclusion criteria: inaccurate response and RT (0.02%), inaccurate response and not fixating the target (1.65%), and RT and not fixating the target (0.07%).

The dependent measures were submitted to a 2 x 2 x 5 mixed factor analysis of variance (ANOVA) with target type (invariable, variable), ISI (50, 900), and bin (1-5). The 30 trials in each block were divided into 5 bins of 6 trials each for analysis. That is, the first six trials of all the blocks were grouped together into the first bin, the next six trials of each block were grouped into the second bin, so on and so forth. For any instances in which the assumption of sphericity was violated, Greenhouse-Geisser correction was used. A Bonferroni correction of .025 was for all planned comparisons unless stated otherwise.

2.2.1 RESPONSE TIME. The LTM template hypothesis predicts faster performance for a LTM template compared to a VWM template. An ANOVA revealed a main effect of target type, $F(1,124) = 5.83$, $p = .017$, $\eta^2_p = .045$. Responses were faster for invariable targets than for variable targets (Figure 6). Although there was no main effect of bin, $F(3.71, 460.42) < 1$, $p = .480$, $\eta^2_p = .007$, there was a significant interaction between bin and target type, $F(3.71, 460.42) = 15.23$, $p < .001 = \eta^2_p = .109$. This interaction was caused by faster RTs for the invariable condition than the variable condition in the later bins (bins 3, 4, & 5), but not in the earlier bins (bins 1, & 2 see Table 1). Furthermore, variable target performance did become slower from bin 1 (*M* = 1127.53 ms) to bin 5 (*M* = 1167.74 ms), $t(63) = -2.762$, $p = .008$, but invariable target performance did become faster from bin 1 (*M* = 1104.64 ms) to bin 5 (*M* = 1038.16 ms), $t(63) = 6.65$, $p < .001$. This quickening of performance across bins for the invariable condition suggests that an invariable target allows for the use of an attentional template that leads to more efficient search.

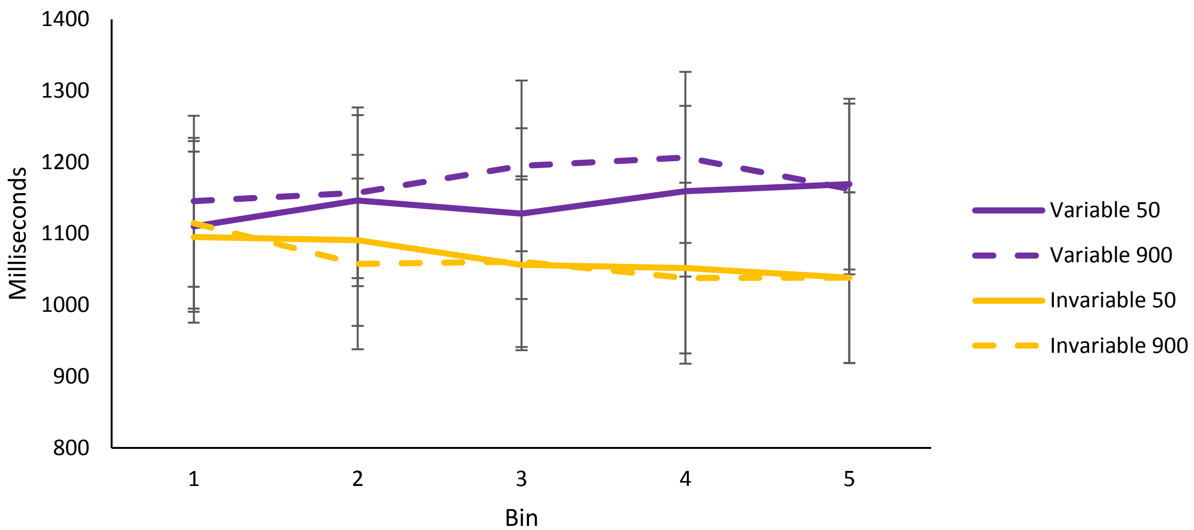

Figure 6. Participants' RTs for the invariable targets (yellow) and the variable targets (purple) by ISI (50 ms, 900 ms) across bins of six trials. Error bars are within confidence intervals based on the between-subjects factor target type.

Table 1.
Mean RT at each bin for both target types.

Bin	Invariable Mean	Variable Mean	*p*-value	Significance
1	1104.64 ms	1127.53 ms	.560	*n.s.*
2	1047 ms	1151.49 ms	.041	*n.s.*
3	1058.3 ms	1161.17 ms	.01	*
4	1033.65 ms	1182.93 ms	.002	*
5	1038.16 ms	1165.74 ms	.002	*

* $p < .01$ Bonferroni correction

ISI had minimal impact on RTs. There was no main effect of ISI, $F(1,124) < 1$, $p = .738$, $\eta^2_p = .001$, no interaction between target type and ISI, $F(1,124) < 1$, $p > .650$, $\eta^2_p = .002$, and no three-way interaction between target type, ISI, and bin, $F(3.71, 460.42) = 1.61$, $p = .174$, $\eta^2_p = .013$. However, there was a significant interaction between bin and ISI, $F(3.713, 460.424) = 2.83$, $p = .028$, $\eta^2_p = .022$. This appears to be caused by a slowing of RT for the 900ms ISI conditions for bins (bin 3 & 4), however, the difference between 900 ms and 50 ms ISI at bins 3 and 4 is not statistically significant (see Table 2).

Table 2.
Mean RT at each bin for both ISIs.

Bin	900 ms	50 ms	*p*-value	Significance
1	1129.74 ms	1102.43 ms	.487	*n.s.*
2	1118.28 ms	1107.22 ms	.773	*n.s.*
3	1127.59 ms	1091.89 ms	.373	*n.s.*
4	1122.04 ms	1105.53 ms	.718	*n.s.*
5	1100.3 ms	1103.60 ms	.937	*n.s.*

* $p < .01$ Bonferroni correction

2.2.2 SEARCH INITIATION. It is possible that storing an attentional template in LTM affects how quickly search is initiated. The search initiation reflects the time required to establish an attentional template. The LTM template hypothesis predicts faster search initiation with an invariable target compared to a variable target. It also predicts faster search initiation for an variable target given sufficient time to establish the template. The ANOVA revealed a significant main effect of target type, $F(1, 124) = 6.32$, $p = .013$, $\eta^2_p = .048$, (Figure 7). Searches for invariable targets were initiated faster than for variable targets. A significant main effect of bin was also found, $F(2.59, 321.11) = 3.94$, $p = .012$, $\eta^2_p = .031$. Although, there was a significant interaction between target type and bin, $F(2.59, 321.11) = 2.92$, $p = .042$, $\eta^2_p = .023$, performance did not improve from bin 1 ($M = 174.25$ ms) to bin 5 ($M = 175.97$ ms) for the variable targets, $t(63) = -.92$, $p = .359$, and performance did not improve from bin 1 ($M = 162.18$ ms) to bin 5 ($M = 165.76$ ms) for the invariable targets, $t(63) = -1.65$, $p = .105$. Furthermore, search initiation for the invariable and variable target conditions was only statistically different at bin 4 (see Table 3).

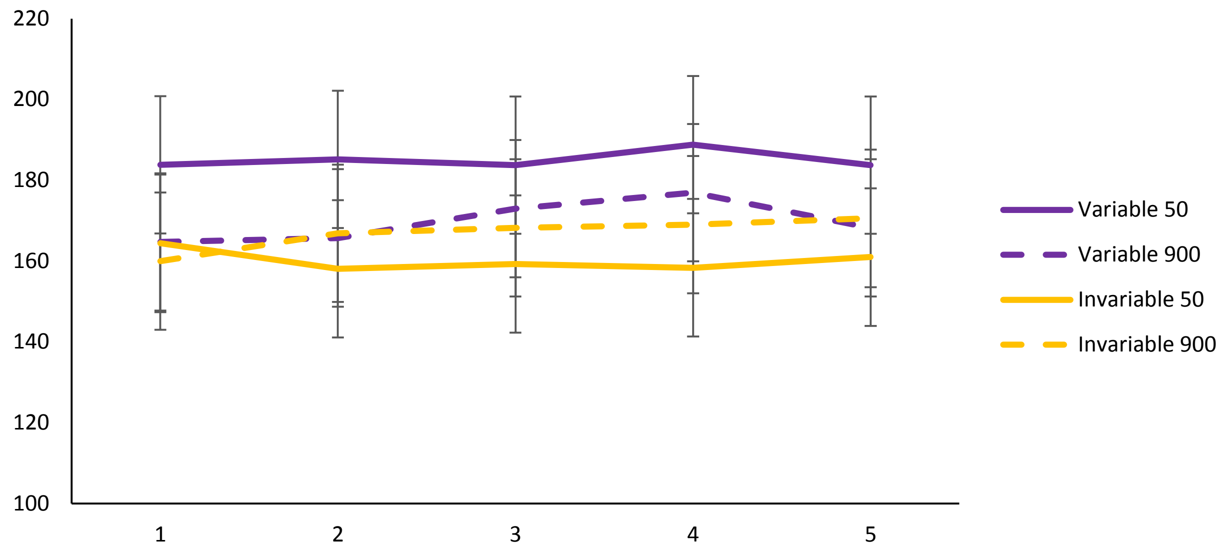

Figure 7. The period of search initiation (duration of the first fixation until the first saccade) for the invariable targets (yellow) and the variable targets (purple) by ISI (50 ms, 900 ms) across bins of six trials. Error bars are within confidence intervals based on the between-subjects factor target type.

Table 3.
Mean Search Initiation at each bin for each target type.

Bin	Invariable Mean	Variable Mean	*p*-value	Significance
1	162.18 ms	174.25 ms	.023	*n.s.*
2	162.48 ms	175.43 ms	.022	*n.s.*
3	163.74 ms	178.36 ms	.011	*n.s.*
4	163.66 ms	182.87 ms	.009	*
5	165.76 ms	175.97 ms	.06	*n.s.*

* $p < .01$ Bonferroni correction

The impact of ISI was moderate. There was no main effect of ISI, $F(1, 124) < 1$, $p = .434$, $\eta^2_p = .005$, and no three-way interaction between ISI, target type, and bin, $F(2.59, 321.11) = 1.69$, $p = .177$, $\eta^2_p = .013$. ISI did produce a significant interaction with target type, $F(2.59, 321.11) = 4.03$, $p = .047$, $\eta^2_p = .031$. This interaction appears to be driven by the variable condition ($M = 185.57$ ms) being slower to initiate search with a 50 ms ISI compared to the invariable condition 50 ms ISI condition ($M = 160.83$ ms), $t(40.54) = 2.59$, $p = .013$. Furthermore, search initiation with a variable target was not significantly different for the 50 ms ISI ($M =$ 185.57 ms) compared to the 900 ms ISI ($M = 170.21$ ms), $t(62) = -1.35$, $p = .182$. Also, ISI produced a significant interaction with bin, $F(2.59, 321.11) = 5.22$, $p = .003$, $\eta^2_p = .040$. This interaction appears to be driven by 50 ms ISI being slower than the 900 ms ISI at bin 1, but this difference is only approaching significance (see Table 4).

Table 4.
Mean Search Initiation at each bin for each ISI.

Bin	900 ms	50 ms	*p*-value	Significance
1	162.34 ms	174.08 ms	.027	*n.s.*
2	166.29 ms	171.61 ms	.351	*n.s.*
3	170.6 ms	171.5 ms	.879	*n.s.*
4	172.94 ms	173.58 ms	.931	*n.s.*
5	169.38 ms	172.56 ms	.585	*n.s.*

* $p < .01$ Bonferroni correction

2.2.3 NAVIGATION. It was predicted that the differences in RT between invariable and variable targets would be explained by differences in the period of navigation (defined as from the first saccade until the first fixation on the target). However, the ANOVA revealed no main effect of target type, $F(1,124) < 1$, $p = .691$, $\eta^2_p = .001$, or bin, $F(4, 496) = 1.39$, $p = .236$, $\eta^2_p = .011$. Invariable targets were not found faster compared to variable targets (Figure 8). However, the ANOVA did reveal an interaction between target type and bin,

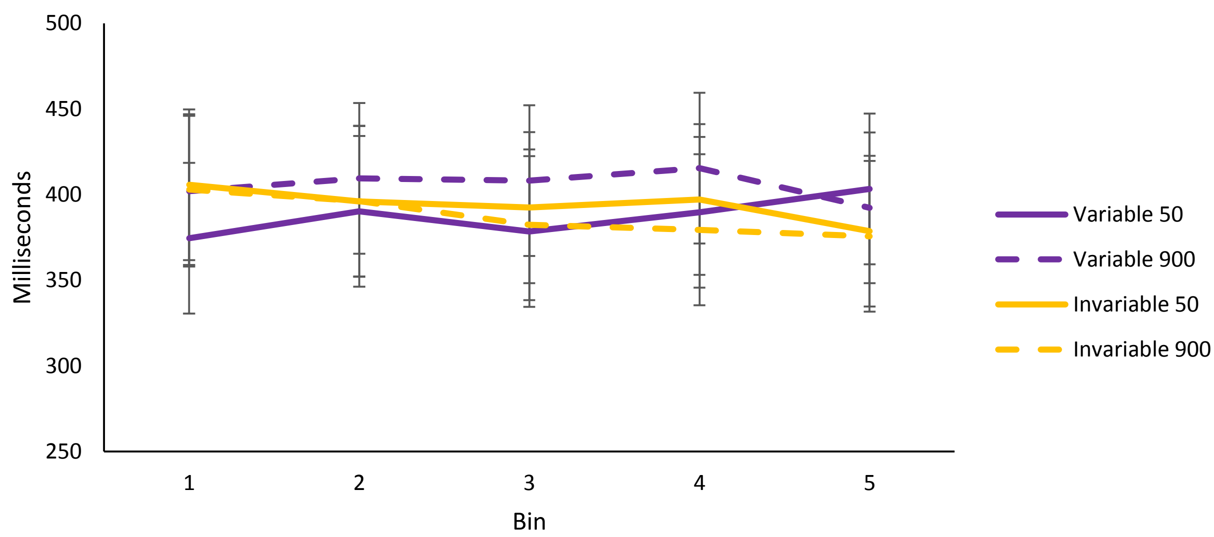

Figure 8. The period of navigation (after the first saccade until the first fixation on the target) for the invariable targets (yellow) and the variable targets (purple) by ISI (50 ms, 900 ms) across bins of six trials. The invariable and variable targets did not differ at any of the bins, $p > .2$. Error bars are within confidence intervals based on the between-subjects factor target type.

F(4,496) = 3.45, *p* = .009, η^2_p = .027. This interaction was caused by faster navigation from bin 1 (*M* = 404.33 ms) to bin 5 (*M* = 377.16) for the invariable targets, *t*(63) = 4.15, *p* < .001, but not from bin 1 (*M* = 388.24) to bin 5 (*M* = 397.8) for the variable targets, *t*(63) = -1.25, *p* > .2. Although this suggests improved navigation for the invariable target, navigation time was not different between the invariable and variable targets at any of the bins.

ISI had no effect on performance during navigation. There was no main effect of ISI, *F*(1, 124) < 1, *p* = .68, η^2_p = .001, no interaction between ISI and target type, *F*(1, 124) < 1, *p* = .386, η^2_p = .006, no interaction between ISI and bin, *F*(4,496) = 1.07, *p* = .372, η^2_p = .009, and no three-way interaction between ISI, target type, and bin, *F*(4,496) = 1.90, *p* = .109, η^2_p = .015.

2.2.4 FIRST SACCADES TO THE TARGET. A measure of navigation includes the number of first saccades to the target. The LTM hypothesis predicts more first saccades to the target with an invariable target. The ANOVA did not reveal a main effect of target type, *F*(1,124) < 1, *p* = .723, η^2_p = .001, a main effect of bin, *F*(4,496) = 1.83, *p* = .122, η^2_p = .015, or an interaction between target type and bin, *F*(4,496) < 1, *p* = .556, η^2_p = .006. The remaining main effect and interactions were not significant, *p* > .326. These results are consistent with the conclusion that invariable targets do not lead to attentional templates that differ in guidance from variable targets.

2.2.5 AVERAGE NUMBER OF DISTRACTORS FIXATED DURING NAVIGATION. A decrease in the number of distractors fixated during the time of period navigation would indicate faster guidance to the target. The ANOVA did not reveal a main effect of target type, *F*(1,124) = 3.05, *p* = .083, η^2_p = .024, a main effect of bin, *F*(3.73, 462.79) = 1.50, *p* = .204, η^2_p = .012, or an interaction between target type and bin, *F*(3.73, 462.79) < 1, *p* = .423, η^2_p = .008. The remaining main effect and interactions were not significant, *p* > .332. As with first saccades to the target, these results are also consistent with the conclusion that invariable targets do not lead to attentional templates that differ in guidance from variable targets.

2.2.6 AVERAGE FIXATION DURATION ON DISTRACTORS DURING NAVIGATION. The LTM template hypothesis predicts shorter fixation durations on distractors with an invariable target. The

ANOVA revealed a main effect of target type, $F(1,124) = 8.71$, $p = .004$, $\eta^2_p = .066$, with longer fixation durations on distractors when the target was variable (Figure 9). The remaining main effects and interactions were not significant, $p > .133$. This suggests invariable targets improve the identification process that is involved in both verification of the target and the rejection of distractors.

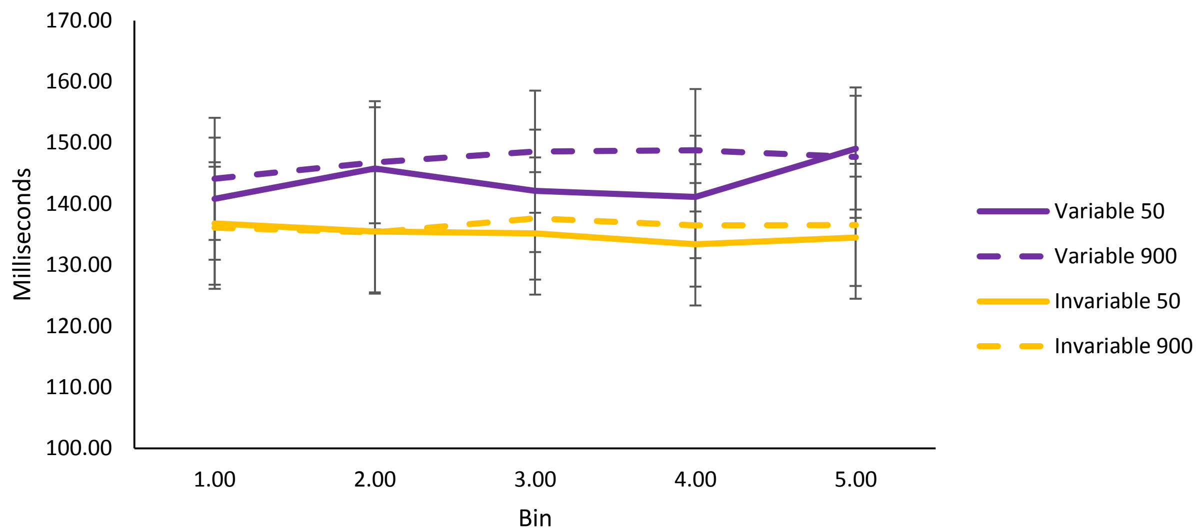

Figure 9. The average fixation duration on distractors during navigation for the invariable targets (yellow) and the variable targets (purple) by ISI (50 ms, 900 ms) across bins of six trials. Error bars are within confidence intervals based on the between-subjects factor target type.

2.2.7 VERIFICATION. Alternatively, the type of template may impact the process of target recognition and decision making during verification. The LTM template hypothesis predicts faster verification with an invariable target. The ANOVA revealed a main effect of target type, $F(1,124) = 7.10$, $p = .009$, $\eta^2_p = .054$. Invariable targets lead to faster responses once the target was fixated compared to variable targets. There was no significant main effect of bin, $F(3.381, 419.21) < 1$, $p = .724$, $\eta^2_p = .004$. However, there was a significant interaction between target type and bin, $F(3.38, 419.21) = 11.764$, $p < .01$, $\eta^2_p = .087$ (Figure 10). This interaction was caused by faster verification for the invariable condition than the variable condition in the later bins (3, 4, & 5), but not in the earlier bins (1 & 2). Consistent with RT, the amount of time to verify the target was the same at bin 1 ($M = 565$ ms) as it was at bin 5 ($M = 591.97$ ms) for the variable targets, *t*(63) = -2.265, $p = .027$, but, the amount of time to verify the target became faster from bin 1 ($M = 538.13$ ms) to bin 5 ($M = 495.24$) for invariable targets, $t(63) = 4.841$, $p < .001$. This suggests that, an invariable target allows for an attentional template to be created that improves target recognition and/or decision making.

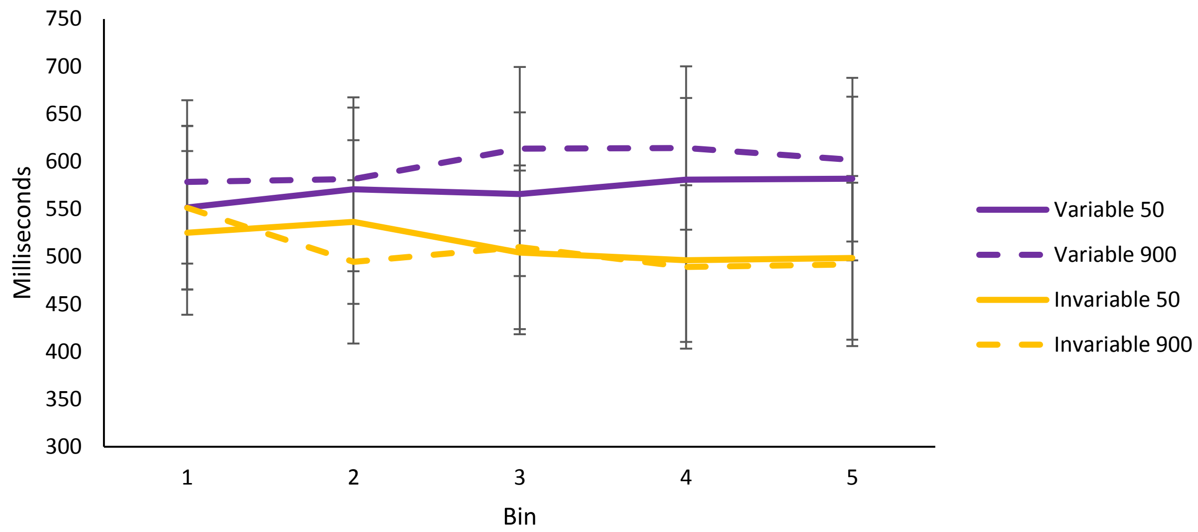

Figure 10. The period of verification (after the first fixation on the target until a response is made) for the invariable targets (yellow) and the variable targets (purple) by ISI (50 ms, 900 ms) across bins of six trials. The invariable targets were recognized faster in bins 3, 4, and 5 than the variable targets with a Bonferroni corrected *p*-value of .01. The Error bars are standard error.

ISI had minimal impact on verification. The main effect of ISI was not significant, $F(1,124) < 1$, $p = .681$, $\eta^2_p = .001$, the interaction between target type and ISI was not significant, $F(1,124) < 1$, $p = .560$, $\eta^2_p = .003$, and there was no three-way interaction between ISI, target type, and bin, $F(3.38, 419.21) = 1.22$, $p = .303$, $\eta^2_p = .010$. There was a significant interaction between bin and ISI, $F(3.38, 419.21) = 3.65$, $p = .01$, $\eta^2_p = .029$. The ISIs did not statistically differ at any of the bins.

2.3 DISCUSSION

The goal of Experiment 1 was to test the LTM template hypothesis that search performance would be fastest with an invariable target. Previous research has shown, using ERPs that an attentional template can be stored in LTM, yet, corresponding behavioral differences between invariable and variable targets (e.g. RTs) has been absent (Carlisle et al., 2011). The results of Experiment 1 supports the LTM template hypothesis. Search performance was faster for the invariable target compared to the variable target overall as demonstrated by faster RTs.

Another goal of Experiment 1 was to explore what part of the search process is improved or aided by the transition of an attentional template from VWM to LTM. One function of attentional template is to bias attention to similar items in the visual environment. The present findings suggest that guidance for a VWM and LTM attentional template do not differ as demonstrated by no differences during navigation. The target type by bin interaction during navigation was caused by navigation becoming faster from bin 1 to bin 5 for the invariable targets only. Yet, the number of distractors fixated during navigation did not decrease across bins. The improved performance supports the learning of the invariable target, however, the learning does not support improved performance compared to a variable target.

Instead, Experiment 1 shows the LTM template hypothesis is supported by faster verification for invariable targets. The second function of an attentional template is to provide a mental representation for comparison to potential targets. This faster verification for invariable targets is demonstrated by shorter fixation durations on distractors, and faster responses once the target is fixated. Furthermore, the difference between the variable and invariable targets on these measures occurs by bin 3. Therefore, verification is faster for invariable targets after about 18 trials. This suggests that it may take more trials to see a behavioral change compared to the rapid change seen with the CDA (3-7 trials).

In addition, Experiment 1 shows the LTM template hypothesis is supported by faster search initiation. Search initiation is defined as the first fixation duration. The first fixation duration with an invariable target for bins 1, 2, and 3 was approaching being significantly shorter than first fixation duration with a variable target. These trends coupled with a statistically shorter duration at bin 4 with an invariable target suggests the first fixation duration may show a similar rapid change as seen with the CDA (3-7 trials). This also suggests an invariable target creates an attentional template that is established faster than a variable target.

Finally, Experiment 1 showed ISI had minimal effects on performance. The only effect of note was the interaction between ISI and target type for search initiation. Invariable targets are initiated faster with a 50 ms ISI than variable targets. This suggests invariable targets create attentional templates that can be established faster or retrieved sooner than an attentional template for a variable target can be established. Previous research shows an attentional template requires at least 200 ms to be effective in aiding performance (Vickery et al., 2005; Wolfe et al., 2004). Yet, search initiation did not differ for variable targets with a 50 ms and 900 ms ISI. This suggests the amount of time required to use an attentional template does not differ by the type of attentional template.

Experiment 1 supports the LTM template hypothesis and that the verification function of an attentional template is improved when a target is stored in LTM. Experiment 2 attempted to replicate the LTM template hypothesis while further investigating the relationship between memory and attention.

CHAPTER 3. EXPERIMENT 2: THE RELATIONSHIP BETWEEN MEMORY AND ATTENTION

Attention is often described as being the gateway to memory (O'Regan & Noë, 2001), however, this relationship is likely not unidirectional. A bidirectional relationship is predicted by instance theory, where by attending to items in the environment leads to the retrieval of prior instances and these instances in turn guide attention. Instance theory proposes the two processes that occur in parallel (Logan, 2002). Based on ERP studies (Carlisle et al., 2011; Gunseli et al, 2014; Reinhart et al., 2014) there appears to be situations where the memory store used to guide attention changes, but there is no observable difference in how the different stores affect attention guidance. This absence of an effect on search behavior could be due to the function of memory as well as the methodological elements of the previous studies. For example, the previous studies (Carlisle et al., 2011; Gunseli et al., 2014) suggest that VWM is recruited each time the target switches regardless of whether the task had been completed with the target previously. This seems counter to instance theory. Furthermore, in Carlisle et al. (2011) and Gunseli et al. (2014) targets were not solely targets and could appear as distractors throughout the experiment. Thus, the current study presented alternating blocks of variable and invariable targets with invariable targets remaining constant across invariable blocks to investigate the relationship between memory and attention. In addition, the relationship between the invariable target and its color and the relationship between the variable target and its color was manipulated by having them appear as distractors in the variable target blocks.

Instance theory predicts more encounters with a particular task results in more episodes that are available later for retrieval. This increase in accessible episodes benefits performance (Logan, 1988, 2002). Having multiple instances for retrieval is less about retrieving all the prior episodes and more about the likelihood that one episode will be retrieved sooner than the algorithm will finish (Logan, 2002). Retrieving a prior instance provides a solution to the task that results in the task to be accomplished faster. Thus, performance on a task that has been encountered before should be faster because LTM has provided the solution to complete the task. At the very least performance should be better than the first encounter with the task when learning has not occurred. LTM guidance is predicted to be faster and last longer (i.e. durable) than VWM. The faster activation should allow for LTM to be used immediately after encountering a previous invariable target following a delay without entering VWM first. This will be referred to as the *durability hypothesis.*

ERP studies examining the CDA do not support the durability hypothesis (Carlisle et al., 2011; Gunseli et al., 2014). In the ERP studies after three, five, or seven trials the target would change to a different Landolt stimulus with a new gap position. The previous target would appear later in the block or experiment as a target again. On the later appearance, instance theory predicts performance should be as good as the previous encounter and should be at least better than the initial encounter. Support of the durability hypothesis would be the absence of the CDA and RTs that are faster compared to the previous run with the target. However, Carlisle et al. (2011) found the CDA was present on the first trial of every run with the same target. This is taken as evidence that VWM is required before LTM is to be used to store the template and guide attention.

The reemergence of the CDA when the target switched to a previously seen target may be understood within the parameters of consistent mapping (Carlisle et al., 2011; Shiffrin & Schneider, 1977). With consistent mapping performance is optimal when the target maintains one identity throughout the task and when the mapping is varied (a previous target can also be a distractor) performance suffers. For example, Shiffrin and Schneider (1977) gave participants memory sets as possible targets in a trial which consisted of multiple frames where the participant decided whether a target was present. In the consistent mapping condition for a trial, the memory set contained all numbers (7, 4, 8, 1) and the distractor set contained all letters (K, G, J, C, M). In the varied mapping condition all of the stimuli were letters. If the memory set on trial one was M, J, D, G then the distractor set on trial two contained M, D, and G. The identity of the M, D, and G switches between trials and performance is hindered by the previous target appearing as a distractor. The difference in performance in Shiffrin and Schneider was not found in Carlisle et al. (2011), but the inconsistent mapping may have impacted the CDA.

The relationship between a target and its features causes changes in the CDA amplitude that reflect the use of VWM. When the target was invariable across blocks (the same gap position) and the color was counterbalanced, the CDA disappeared across blocks (Carlisle et al., 2011). In this case, the target is never a distractor on absent trials resulting in consistent mapping. Once the target identity is switched every three to seven trials to establish how quickly the CDA disappeared, varied mapping is used. This suggests information learned to complete the visual search task could impact what episodes are retrieved when shown the target cue. It is possible the sequence of the target cue through the search array is an instance or separate instances with the same item that result in different outcomes. More importantly, the evidence is based upon keeping the target invariable or changing the target after short runs to determine how long before the passing of the attentional template occurs, but it is unclear how using VWM or LTM changes search behavior.

A corollary to the durability hypothesis is the *consistent mapping hypothesis*. According to the consistent mapping hypothesis a LTM template can be accessed without reactivation in VWM as long as the target maintains one identity. The durability of the LTM target is predicted to heighten lower level perceptual processes that are stimulated for target features. Once the target is switched to a new target after an invariable target, a distractor that matches the feature information of the invariable target is predicted to attract attention. Once the distractor is focused it has to be ruled out as the target for the current trial and relabeled as a distractor. A distractor that matches the invariable target is predicted to disrupt performance because in the current situation the feature information is important for guidance and not verification. In Carlisle et al. (2011) the color information would always direct attention to the red Landolt in the array, but the gap information would be needed to determine if Landolt was the target. The current study creates a situation where the color is integral to finding the target and the gap is reported to complete the task, but the gap is not integral to finding the target. The distinction between whether the information is being used to aide guidance or verification should impact the level of the interference.

According to the durability hypothesis, a LTM template is easily accessible on subsequent encounters. There is evidence that an instance contains specific information required to complete the task (Lassaline & Logan, 1993). The durability of the LTM template may be limited to retrieving instances on the target cue screen. Experiment 1 did not find a distinction between LTM template and VWM template guidance. The instance retrieved on the target cue screen might still impact performance on the search array. The retrieved instance might provide a higher fidelity target representation as a reference to compare a potential target against. This would suggest the durability of the LTM template persists to the search array and possibly longer. An unanswered question is whether the long lasting durability of the LTM template is limited to ease of reactivation of the template when the template is needed to complete the task or whether the mere presence of the item in the visual field is enough to trigger retrieval of an instance. Instance theory takes into account how information in the environment and expectations impact attention and performance (Logan, 2002). This suggests a distractor that is similar to an invariable target would cause interference on a trial where the objective (e.g. the target) has changed.

Based upon the consistent mapping hypothesis, it is unclear whether there is residual perceptual stimulation for the information or whether an instance is triggered upon encountering the previous target. This is similar to a debate in the priming literature regarding priming being the result of perception and attention or higher order response selection (Becker, 2008). Thus, if varied mapping causes interference because there is residual perceptual activation than a distractor that matches the invariable target and the previous variable target should produce more interference compared to a randomly chosen distractor. The inference caused by the invariable target and previous variable target should produce the same amount of interference compared to each other. This would support that guidance functions independently and guidance does not function differently based on the memory representation. Alternatively, the durability of the LTM template could result in a longer persistence of the activation past the last time the template was utilized and trigger the retrieval of an instance. This would lead to greater interference by a distractor matching the invariable target and to the distractor having to be identified as a distractor and not a target. The relabeling would require learning and impact distractor rejection. The invariable target color distractor having longer fixation durations compared to the variable target color distractor and a color only associated with being a distractor would support learning the invariable target leads to greater interference. The current experiment tested the *LTM retrieval hypothesis* which predicts that encounters with the invariable target as a distractor in the same context where it appeared as a target will activate previous episodes. The retrieval of these episodes will cause interference in performance.

A LTM template with durability would predict faster activation of the LTM template with future encounters providing a solution to accomplish a task. However, Carlisle et al. (2011) found the CDA to reappear each time a previously learned target became the objective of the search task again. This suggests that VWM is recruited before LTM can bias the allocation of attention. To test whether LTM can bias attention immediately, Experiment 2 manipulated variable and invariable targets in the same experiment. A run of invariable targets always proceed a run of variable targets to expand the LTM template hypothesis and test the durability hypothesis. Instance theory does not predict using VWM on subsequent encounters. The reemergence of VWM could be due to consistent mapping. Thus in Experiment 2, during variable target trials distractors were manipulated to match the invariable target or the previous variable target. Finally, Experiment 2 examined the LTM retrieval hypothesis by examining the interference caused by target color distractors.

Experiment 2 continued to investigate the relationship between memory and attention by testing the durability, consistent mapping, and LTM retrieval hypotheses (see Table 5 for each hypothesis and critical analysis). This was done by presenting participants invariable and variable target types and manipulating

Table 5.
The critical analysis for each hypothesis in Experiment 2.

Hypothesis	Analysis			
	Response Time	Search Initiation	Navigation	Verification
LTM template	✓	✓		✓
Durability	✓	✓		
Consistent mapping	✓	✓		
LTM retrieval			✓	

distractor features. Experiment 2 also continued to investigate the Experiment 1 finding that a LTM template impacts the attentional template function as a reference to compare potential targets against. Due to the effects of invariable targets during verification in Experiment 1 occurring around 18 trials, the number of trials in a block in Experiment 2 was reduced from 30 to 20.

3.1 METHOD

3.1.1 PARTICIPANTS. Ninety-nine participants were recruited from the Louisiana State University Psychology pool and received course credit for their participation. Analysis included 96 participants (80 female, average age = 20.02) after three participants were replaced for performing at or below chance (50%). All participants reported normal color vision and normal or corrected to normal vision. Thirty-two participants participated in each of the conditions.

3.1.2 POWER. The partial eta squared from the mixed factor ANOVA with target type (invariable, variable) and bin (5) from Experiment 1 was converted to the effect size using G*Power. The partial eta squared was .109 and calculated effect size was .350. The effect size was used to estimate the number of participants in Experiment 2 to find the two-way interaction of target type and bin with 80 percent power. In Experiment 2 the target type variable is within subjects and not between subjects as it was in Experiment 1. Entering the effect size of .349 into G*Power for a mixed factor ANOVA within-between interaction produced a total sample size of 12 participants. Based on this information, I chose to keep the number of participants per condition to 32 because the number of trials per block was reduced.

3.1.3 APPARATUS AND STIMULI. The same stimuli (objects and colors) as in Experiment 1 were used in Experiment 2.

3.1.4 DESIGN. The experiment design was a 2 x 3 x 12 mixed model. The within subject factors were target type and trial. Participants completed 13 blocks of 20 invariable trials alternated with 12 blocks of 20 variable trials. (The unequal number of blocks allowed an invariable block to always proceed a variable block and created an equal number of switches between block types.) The between subjects factor was distractor type. Participants experienced one of the three possible distractor types in the variable target blocks (Table 6). The three distractor types included: (1) a distractor that matched the invariable target color from the previous invariable block (invariable target color distractor), (2) a distractor that matched the variable target color from the previous variable trial (variable target color distractor), and (3) none of the distractors shared a color from the target on the previous invariable block or the previous variable trial (non-target color distractors).

Table 6.
A description of the different types of distractors in the variable target blocks

Distractor Type	Description
Invariable Target Color	Shares the same color as the target from the previous block
Variable Target Color	Shares the same color as the target from the previous trial
Non-Target Color	Never shares the same color as the target from the previous block or trial

All dependent measures were the same as Experiment 1. However, first saccades to the target were not examined because first saccades to the target rarely occurred for either target type.

3.1.5 PROCEDURE. Participants provided informed consent prior to starting the experiment. Instructions were presented on screen and read aloud to the participant. Instructions were the same as Experiment 1. Following instructions, participants went through a calibration and validation process to set-up the eye tracker. At the start of the experiment the computer randomly assigned the color of the invariable target. All participants had an invariable target block first followed by a variable target block. The block order always consisted of an invariable block followed by a variable block for a total of 25 blocks (13 invariable and 12 variable). Participants were randomly assigned to one type of variable target distractor condition. Unlike Experiment 1, the invariable target color remained the same for all invariable blocks. In addition, recalibration was done after every three blocks to ensure that it occurred equally often after invariable and variable blocks of trials.

In the invariable target color distractor condition, a distractor in each trial in the variable block was the same color as the invariable target and the target color from the previous variable trial did not appear as a distractor color (Figure 11). In the non-target color distractor condition, all the distractors in each variable trial did not match the invariable target color or the target color on the previous variable trial (Figure 12). Finally, in the variable target color distractor condition, a distractor in each trial in the variable block was the same color as the previous variable target trial and the invariable target color did not appear as a distractor (Figure 13).

Figure 11. The figure represents the variable block invariable target color condition. In the top row is the invariable target block that preceded the variable block invariable target color condition. The invariable target was pink in all 20 trials in a block. In the bottom row is the variable block invariable target color condition. Pink was never the target. Pink appeared as a distractor in all 20 trials in a block. The olive green color did not appear as a distractor when the target switched to blue. Blue was not a distractor in trial 3.

Figure 12. The figure represents the variable target block non-target color distractors condition. In the top row is the invariable target block that preceded the variable target block non-target color distractors condition. The invariable target was pink in all 20 trials in a block. In the bottom row is the variable target distractors block. Pink was never a target or a distractor. The previous target color was never a distractor on the following trial. Olive green did not appear in trial 2 and blue did appear in trial 3.

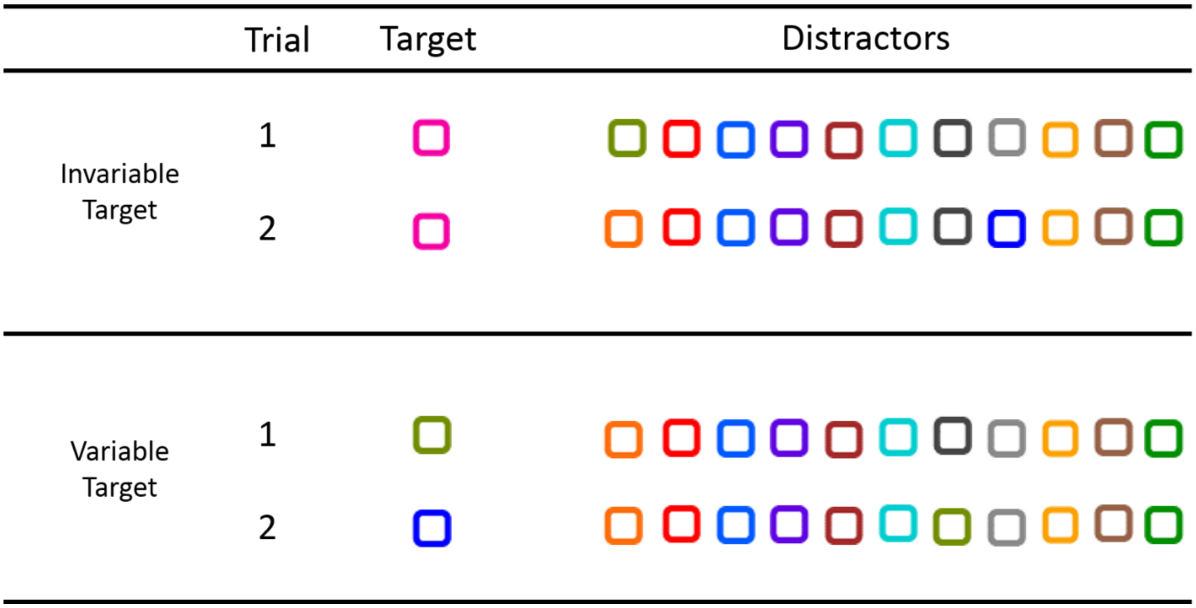

Figure 13. The figure represents the variable target block variable target color condition. In the top row is the invariable target block that preceded the variable target previous trial distractor condition. The invariable target was pink in all 20 trials in a block. In the bottom row is the variable target variable distractor block. Pink was never a target or a distractor. The olive green color did appear as a distractor when the target switches to blue. Blue was a distractor in trial 3.

3.2 RESULTS

Performance was good with an overall accuracy of 95% (non-target color distractor condition = 96.4%, invariable target color distractor condition = 95.2%, variable target color distractor condition = 94.7%). Trials were excluded for inaccurate responses, RT, and when the target was not fixated. (Fixating the target was defined by a fixation that fell within the circular interest area sustaining 2.5° of visual angle surrounding the target.) Overall, 9% of trials were excluded. The following percentages of trials were excluded for each of the exclusion criteria: inaccurate responses (7.23%), with RT more than 3 standard deviations above or below the mean (4.19%), and when the target was not fixated (7.33%). The following percentages of trials were excluded for meeting two of the exclusion criteria: inaccurate response and not fixating the target (4.59%), and RT and not fixating the target (0.16%).

Experiment 2 was divided into four separate analyses. For each measure, only accurate trials were analyzed where the eyes fixate the target from the first 12 blocks. For any instances in which the assumption of sphericity was violated, Greenhouse-Geisser correction was used. A Bonferroni correction of .025 was for all planned comparisons unless stated otherwise.

3.2.1 LTM TEMPLATE HYPOTHESIS. The LTM template hypothesis predicts a LTM template leads to faster performance. In Experiment 1, the LTM template was found to lead to faster verification. To test the LTM template in Experiment 2, the invariable and variable target blocks from only the non-target color distractors condition were examined. All dependent measures were submitted to a 2 x 5 repeated measures ANOVA with target type (invariable, variable) and bin (1-5). A bin was composed of the first four trials of all the blocks grouped together (except for the last invariable block), the next four trials of each block grouped into the second bin, so on and so forth.

3.2.1.1 Response Time. The LTM template hypothesis predicts performance with an invariable target to be faster than performance with a variable target. An ANOVA revealed a main effect of target type, $F(1,31) = 4.87$, $p = .035$, $\eta^2_p = .136$, and a main effect of bin, $F(4,124) = 2.494$, $p = .046$, $\eta^2_p = .074$. Invariable targets were found faster than variable targets (Figure 14). Furthermore, a significant interaction was found between

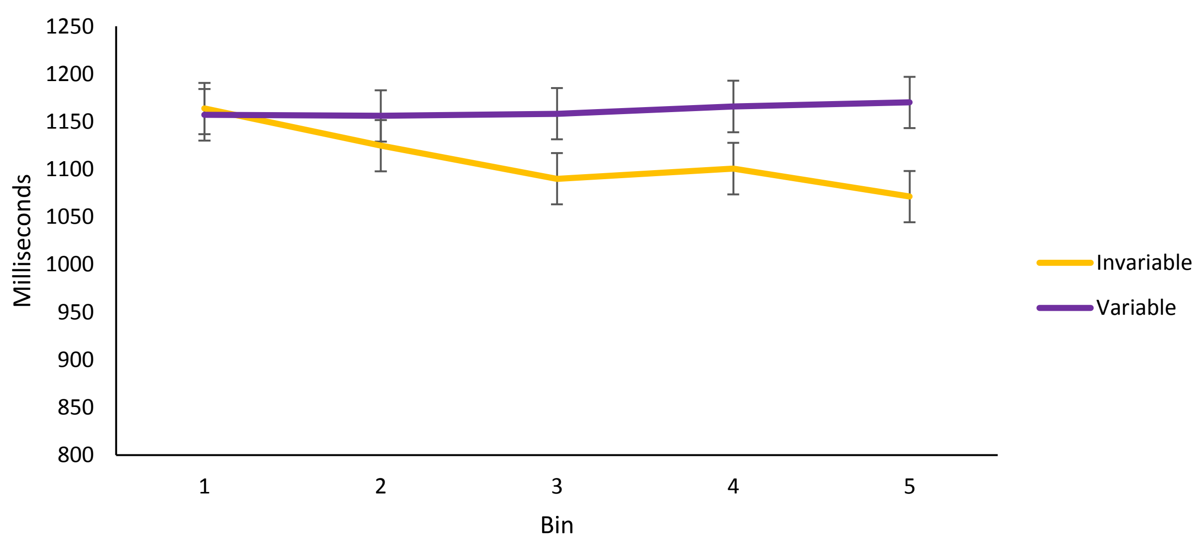

Figure 14. Participants' RTs for the invariable targets (yellow) and the variable targets (purple) by bins of four trials from the non-target color distractor condition. Error bars are pooled within confidence intervals.

target type and bin, $F(3.268,101.314) = 4.7$, $p = .003$, $\eta^2_p = .133$. This interaction was caused by faster RTs for bin 5 for the invariable condition compared to the variable condition, but not in the earlier bins

(bins 1, 2, 3, & 4 see Table 7). Variable target performance did not differ from bin 1 (M = 1157.25 ms) to bin 5 (M = 1170.11 ms), $t(31) = -.526$, $p = .602$, and invariable target performance became faster from bin 1 (M = 1163.76 ms) to bin 5 (M = 1071.30 ms), $t(31) = 6.27$, $p < .001$.

Table 7.
Mean RT at each bin for both target types in the non-target color distractor condition.

Bin	Invariable Mean	Variable Mean	*p*-value	Significance
1	1163.76 ms	1157.25 ms	.838	*n.s.*
2	1124.78 ms	1156.30 ms	.310	*n.s.*
3	1090.04 ms	1158.29 ms	.02	*n.s.*
4	1100.67 ms	1165.97 ms	.013	*n.s.*
5	1071.30 ms	1170.11 ms	.001	*

* $p < .01$ Bonferroni correction

3.2.1.2 Search Initiation. The LTM template hypothesis predicts search initiation to be faster when the target is invariable compared to a variable target. An ANOVA revealed a main effect of target type, $F(1,31) = 28.46$, $p < .001$, $\eta^2_p = .479$, and a main effect of bin, $F(3.086,95.667) = 3.72$, $p = .013$, $\eta^2_p = .107$. Search initiation occurred more quickly in the invariable target condition than the variable target condition. Furthermore, a significant interaction was found between target type and bin, $F(4,124) = 4.33$, $p = .003$, $\eta^2_p = .123$. This interaction was caused by faster search initiation for the later bins (bins 2, 3, 4, & 5 see Table 8) for the invariable condition compared to the variable condition, but not for bin 1. Variable target performance did not differ from bin 1 (M = 179.72 ms) to bin 5 (M = 180.30 ms), $t(31) = -.617$, $p = .542$, and invariable target performance became faster from bin 1 (M = 174.92) to bin 5 (M = 160.59), $t(31) = 4.16$, $p < .001$. Therefore, an invariable target allows for an attentional template to be created that initiates search sooner (Figure 15).

Table 8.
Mean search initiation at each bin for both target types.

Bin	Invariable Mean	Variable Mean	*p*-value	Significance
1	174.92 ms	178.72 ms	.223	*n.s.*
2	164.95 ms	180 ms	< .001	*
3	163.9 ms	176.08 ms	.004	*
4	164.55 ms	177.04 ms	.001	*
5	160.59 ms	180.30 ms	< .001	*

* $p < .01$ Bonferroni correction

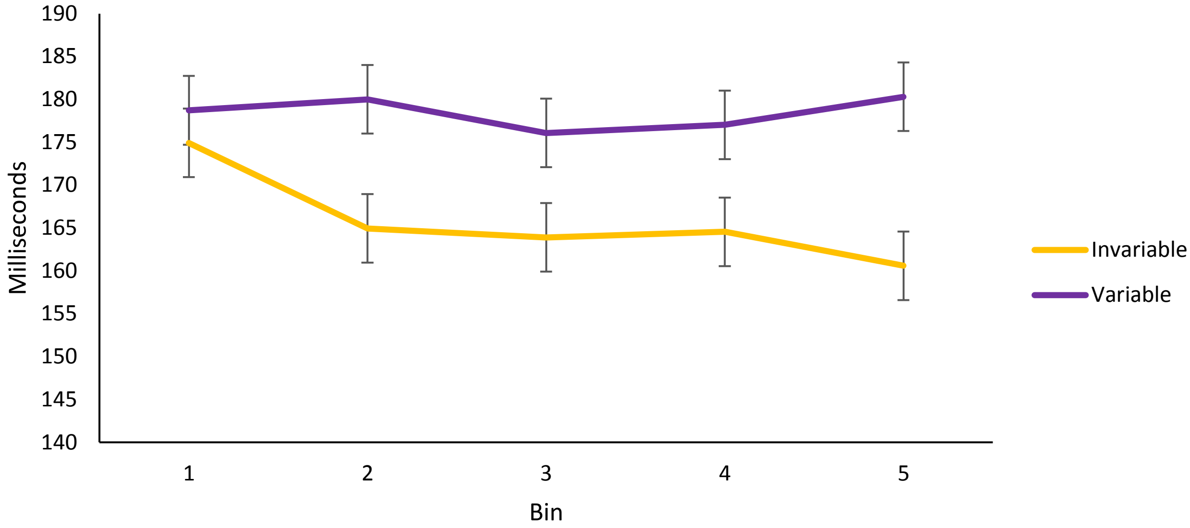

Figure 15. Search Initiation for each target type by block. Error bars are pooled within confidence intervals.

3.2.1.3 Navigation. The LTM template hypothesis predicts navigation time will not differ when using an invariable or variable target based on Experiment 1. An ANOVA revealed no main effect of target type, $F(4,124) = 1.28$, $p = .283$, $\eta^2_p = .04$, or bin, $F(1,31) < 1$, $p = .975$, $\eta^2_p < .001$. There was a significant interaction between target type and bin, $F(4,124) = 2.56$, $p = .042$, $\eta^2_p = .076$ (Figure 16). The invariable and variable

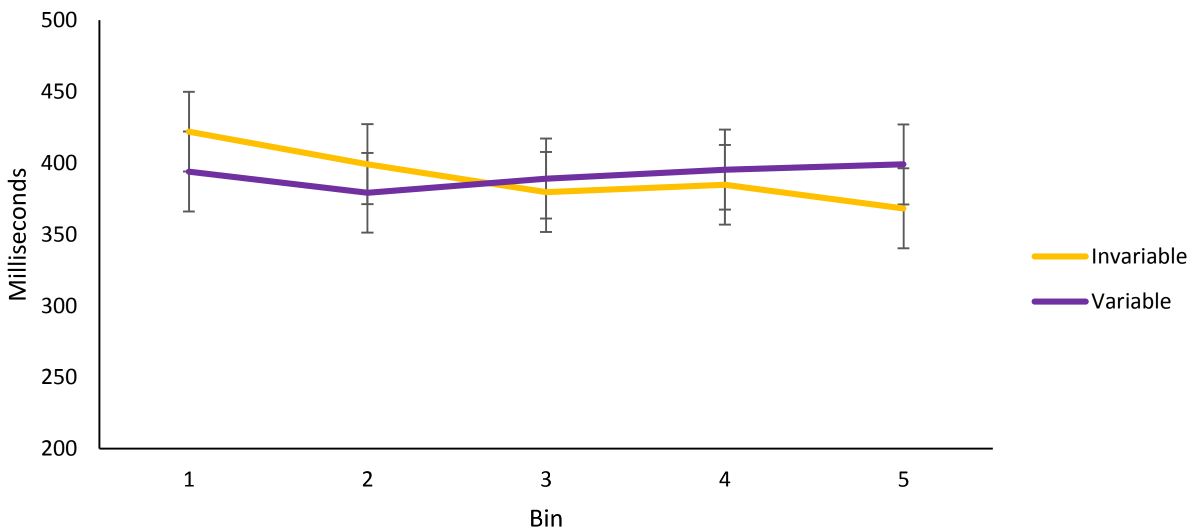

Figure 16. Navigation for each target type by bin. Error bars are pooled within confidence intervals.

targets did not differ in performance at any of the bins, $p > .2$. The variable target performance did not differ from bin 1 ($M = 394.03$) to bin 5 ($M = 389.99$), $t(31) = -.282$, $p = .780$. Invariable target performance became faster from bin 1 ($M = 421.96$) to bin 5 ($M = 368.25$), $t(31) = 3.13$, $p = .004$. This supports learning of the invariable target.

3.2.1.4 Average Number of Distractors Fixated during Navigation. In addition to the navigation time period, changes in the number of distractors fixated can indicate guidance. The LTM template hypothesis predicts fewer distractors to be fixated with an invariable target. The ANOVA revealed a main effect of target type, $F(1,31) = 7.53$, $p = .01$, $\eta^2_p = .195$. Although there was no main effect of bin, $F(2.898, 89.846) = 2.15$, $p = .101$, $\eta^2_p = .065$, there was a significant interaction between target type and bin, $F(1,124) = 3.35$, $p = .012$, $\eta^2_p = .097$. This interaction was caused by more distractors being fixated during the early bins (bins 1, & 2) for the invariable condition than the variable condition, but not for the later bins (bins 3, 4, & 5, see Table 9). The number of distractors fixated did not change from bin 1 to bin 5 for the variable target condition, $t(31) = -.02$, $p = .984$, but the number of distractors decreased from bin 1 to bin 5 for the invariable target condition, $t(31) = 2.63$, $p = .013$. These findings also support the invariable target was learned.

Table 9.
Mean number of distractors fixated during navigation for both target types by bin.

Bin	Invariable Mean	Variable Mean	*p*-value	Significance
1	4.5	3.5	.004	*
2	4.3	3.1	.001	*
3	3.7	3.3	.196	*n.s.*
4	3.9	3.4	.220	*n.s.*
5	3.7	3.5	.439	*n.s.*

* $p < .01$ Bonferroni correction

3.2.1.5 Average Fixation Duration on Distractors during Navigation. The LTM template hypothesis predicts shorter fixation durations on distractors as support for improved verification with an invariable target based on the findings from Experiment 1. An ANOVA revealed a main effect of target type, $F(1,31) = 14.38$, $p = .001$, $\eta^2_p = .313$. Distractors were fixated for a shorter period of time for the invariable condition ($M = 134.40$ ms) than the variable condition ($M = 145.94$ ms). There was no main effect of bin, $F(4,124) < 1$, $p = .754$, $\eta^2_p =$

.015 and no significant interaction between target type and bin, $F(4,124) = 1.40$, $p = .236$, $\eta^2_p = .043$. An invariable target leads to faster distractor rejection.

3.2.1.6 Verification. The LTM template hypothesis predicts faster verification with an invariable target compared to a variable target. An ANOVA revealed a main effect of target type, $F(1,31) = 6.83$, $p = .014$, $\eta^2_p = .181$. Responding to the target after it was fixated occurred more quickly in the invariable target condition than in the variable target condition (Figure 17). There was no main effect of bin, $F(4,124) < 1$, $p = .813$, $\eta^2_p = .013$, and no significant interaction between target type and bin, $F(1,124) < 1$, $p = .564$, $\eta^2_p = .023$. Planned comparisons were performed because the difference between the invariable and variable targets found in Experiment 1 occurred during verification. The verification of the target was faster for the invariable condition at bin 5 than the variable condition, but not at the earlier bins (bins 1, 2, 3, & 4, see Table 10). This is in line with the Experiment 1 finding that the separation begins around 20 trials for verification. The difference between verification at bin 1 and bin 5 for the invariable targets was not significantly different, $t(31) = 1.8$, $p = .082$, and the difference between bin 1 and bin 5 for the variable targets was not significantly different, $t(31) = -.306$, $p = .761$.

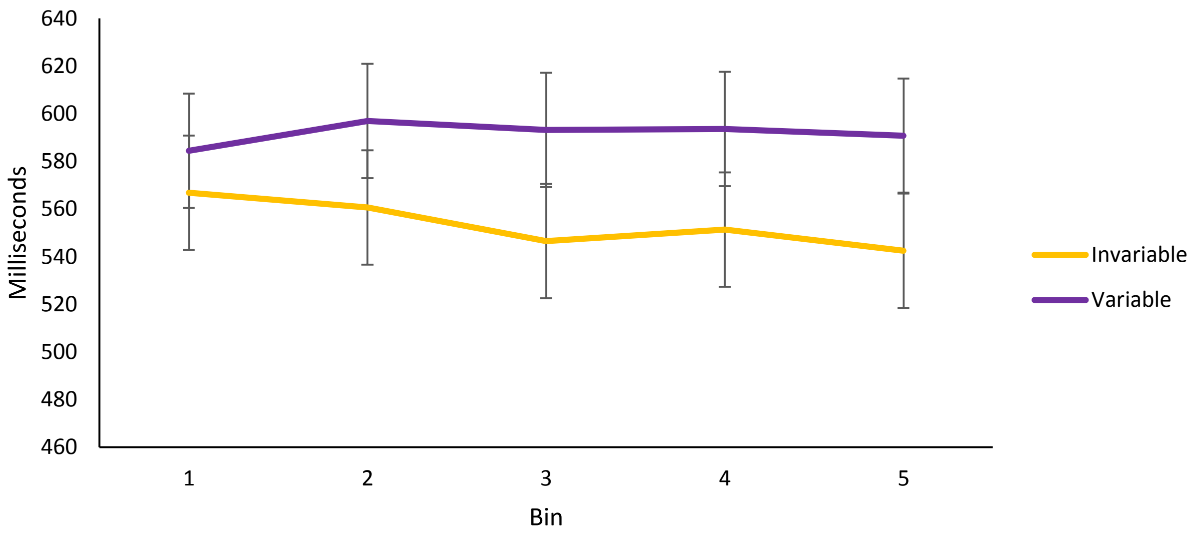

Figure 17. Verification for each target by bin. Error bars are pooled within confidence intervals.

Table 10.
Mean verification at each bin for both target types.

Bin	Invariable Mean	Variable Mean	*p*-value	Significance
1	566.88 ms	584.49 ms	.420	*n.s.*
2	560.66 ms	596.9 ms	.081	*n.s.*
3	546.5 ms	593.17 ms	.015	*n.s.*
4	551.38 ms	593.56 ms	.04	*n.s.*
5	542.46 ms	590.82 ms	.01	*

* $p < .01$ Bonferroni correction

3.2.1.7 Summary. The LTM template hypothesis was supported by a significant interaction between target type (invariable vs variable) and bin with RT and search initiation. A significant interaction between target type and bin was not found with verification, although invariable and variable targets differed at bin 5. The difference in verification performance may take more trials to see than the difference in search initiation or the CDA. However, a main effect of target type was found with verification and supports invariable targets effect target recognition and/or decision making differently than a variable target. The main effect of target type with fixation duration on distractors also suggests an invariable target effects target recognition and/or decision making differently than a variable target. Finally, the target type by bin interaction with navigation supports learning of the LTM template. An invariable target did not produce faster navigation than a variable target, but performance improved from bin 1 to bin 5 demonstrated that the target had been learned.

3.2.2 DURABILITY HYPOTHESIS. The durability hypothesis predicts a LTM template allows for faster activation and immediate use following a delay. Unlike Experiment 1, Experiment 2 had the same invariable target on all repetition trials intermixed with blocks of variable target trials. To assess whether an invariable target requires relearning following a delay or whether an invariable target can be activated faster, the early bins from each block were compared. To test the durability hypothesis, performance in bin 1, bin 2, and bin 3 were compared separately across blocks for the invariable target blocks and variable target blocks in the non-target color distractors condition. These three bins were chosen because invariable and variable performance differed as early as bin 2 for search initiation and as early as bin 3 for RT. Dependent measures from bins 1, 2, 3 were submitted to separate 2 x 6 repeated measures ANOVAs with target type (invariable, variable) and block (1-6).

3.2.2.1 Response Time. The durability hypothesis predicts faster bin 1 response times in the later blocks for an invariable target compared to variable target. The ANOVA did not find a main effect of target type, $F(1, 31) < 1$, $p = .813$, $\eta^2_p = .002$. There was a main effect of block, $F(5, 155) = 8.42$, $p < .001$, $\eta^2_p = .214$ and a significant interaction between target type and block, $F(5, 155) = 4.57$, $p = .001$, $\eta^2_p = .128$. This interaction was caused by bin 1 in block 1 (*M* = 1372.15 ms) being slower than bin 1 in block 6 (*M* = 1056.80 ms) for the invariable targets, $t(31) = 5.99$, $p < .001$. Bin 1 in block 1 (*M* = 1216.46 ms) did not differ from bin 1 in block 6 (*M* = 1139.97 ms) for the variable targets, $t(31) = 1.28$, $p = .211$. Furthermore, performance between the invariable target and variable target differed at block 1 and not at the later blocks (2, 3, 4, 5, and 6 see Table 11). These results suggest the performance with an invariable target improves across blocks for the first four trials, but the invariable target starts in VWM with each new encounter after a delay.

Table 11.
RT for bins 1 and 2 by block.

		Block					
Bin	Target type	1	2	3	4	5	6
1	Invariable	1372.15 *	1230.43	1182.09	1059.62	1105.91	1056.80
	Variable	1216.46 *	1138.60	1213.24	1146.73	1105.18	1139.97
2	Invariable	1318.08 *	1119.60	1158.39	1021.46 *	1074.74	1032.48
	Variable	1167.71 *	1080.70	1185.24	1170.36 *	1114.68	1138.70

* $p < .008$ Bonferroni correction

The durability hypothesis predicts faster bin 2 response times in the later blocks for an invariable target compared to variable target. The ANOVA did not reveal a main effect of target type, $F(1, 31) < 1$, $p = .477$, $\eta^2_p = .016$. There was a main effect of block, $F(3.87, 119.91) = 4.69$, $p = .002$, $\eta^2_p = .131$ and a significant interaction between target type and block, $F(5, 155) = 4.74$, $p < .001$, $\eta^2_p = .133$. This interaction was caused by bin 2 in block 1 (*M* = 1318.08 ms) being slower than bin 2 in blocks 6 (*M* = 1032.48 ms) for the invariable targets, $t(31) = 6.04$, $p < .001$. Bin 1 in block 1 (*M* = 1167.71 ms) did not differ from bin 1 in block 6

(M = 1138.70 ms) for the variable targets, $t(31) < 1$, $p = .647$. In addition, the invariable target was found faster than the variable target for bin 2 in block 4 (Table 11).

The ANOVA for bin 3 revealed a main effect of target type, $F(1, 31) = 4.31$, $p = .046$, $\eta^2_p = .122$, and a main effect of block, $F(5, 155) = 4.93$, $p < .001$, $\eta^2_p = .137$. The interaction between target type and block was not significant, $F(5, 155) = 1.59$, $p = .165$, $\eta^2_p = .049$. The invariable target was found faster the variable target.

3.2.2.2 Search Initiation. The durability hypothesis predicts faster bin 1 search initiation in the later blocks for an invariable target compared to variable target. The ANOVA did not reveal a main effect of target type, $F(1, 31) = 1.52$, $p = .227$, $\eta^2_p = .047$. There was a main effect of block, $F(3.75, 166.28) = 9.01$, $p < .001$, $\eta^2_p = .225$, and a significant interaction between target type and block, $F(3.35, 103.77) = 8.17$, $p < .001$, $\eta^2_p = .209$. This interaction was caused by bin 1 in block 1 (M = 208.91 ms) being slower to initiate than bin 1in block 6 (M = 161.67 ms) for the invariable target, $t(31) = 4.16$, $p < .001$. Bin 1 in block 1 (M = 176.28 ms) did not differ from bin 1 in block 6 (M = 172.85 ms) for the variable targets, $t(31) < 1$, $p = .550$. Performance differed between the invariable target and variable target for bin 1 in block 1 and block 3, but not the remaining blocks (2, 4, 5, and 6). Search initiation was slower for bin 1 in block 1 with an invariable target compared to a variable target, but search initiation was faster for bin 1 in block 3 with an invariable target compared to a variable target (Table 12).

The durability hypothesis predicts faster bin 2 search initiation in the later blocks for an invariable target compared to variable target. The ANOVA revealed a main effect of target type, $F(1, 31) = 16.11$, $p < .001$, $\eta^2_p = .342$, and a main effect of block, $F(2.59, 80.34) = 4$, $p = .014$, $\eta^2_p = .114$. Search was initiated faster for invariable targets compared to variable targets. These findings were qualified by a significant interaction between target type and block, $F(3.39, 105.21) = 3.8$, $p = .009$, $\eta^2_p = .109$. This interaction was caused by bin 2 in block 1 (M = 195.21 ms) being slower than block 6 (M = 159.97 ms) for the invariable target, $t(31) = 6.51$, $p < .001$. Bin 2 in block 1 (M = 180.66 ms) did not differ from bin 2 in block 6 (M = 183.17 ms) for the variable target, , $t(31) = -.188$, $p = .852$. Furthermore, search initiation was faster for the invariable target compared to the variable target at bin 2 in blocks 3 and block 4 (Table 12).

The ANOVA for bin 3 revealed a main effect of target type, $F(1, 31) = 7.62$, $p = .01$, $\eta^2_p = .197$, and a main effect of block, $F(5, 155) = 3.26$, $p = .008$, $\eta^2_p = .095$. These findings were qualified by a significant interaction between target type and block, $F(5, 155) = 3.97$, $p = .002$, $\eta^2_p = .113$. This interaction was caused by bin 3 in block 1 ($M = 185.19$ ms) being slower than bin 3 in block 6 ($M = 162.24$ ms) for the invariable target, $t(31) = 3.16$, $p = .003$, but bin 3 in block 1 ($M = 173.79$ ms) did not differ from bin 3 in block 6 ($M = 180.45$ ms) for the variable target, $t(31) = -.815$, $p = .421$. In addition, search initiation was faster for the invariable target compared to the variable target at bin 5 and bin 6 showed a strong trend (Table 12).

Table 12.
Search initiation for bins 1, 2, and 3 by block.

		Block					
Bin	Target type	1	2	3	4	5	6
1	Invariable	208.19	180.25	165.99 *	175.69	158.94	161.67
	Variable	176.28	189.43	187.42 *	173.88	172.82	172.85
2	Invariable	195.21	160.39	155.80 *	156.13 *	158.06	159.97
	Variable	180.66	167.68	170.56 *	178.65 *	171.80	183.17
3	Invariable	185.19	172.88	157.18	154.70	152.69 *	162.24
	Variable	173.79	174.73	168.99	176.61	176.84 *	180.45

* $p < .008$ Bonferroni correction

3.2.2.3 Navigation. The durability hypothesis predicts faster bin 1 navigation in the later blocks for an invariable target compared to variable target. The ANOVA did not reveal a main effect of target type, $F(1, 31) < 1$, $p = .332$, $\eta^2_p = .030$, a main effect of block, $F(5, 155) < 1$, $p = .532$, $\eta^2_p = .026$, or an interaction between target type and block, $F(5, 155) = 2.01$, $p = .08$, $\eta^2_p = .061$.

The ANOVA for bin 2 did not reveal a main effect of target type, $F(1, 31) = 1.21$, $p = .280$, $\eta^2_p = .038$, a main effect of block, $F(5, 155) < 1$, $p = .517$, $\eta^2_p = .027$, or an interaction between target type and block, $F(5, 155) = 1.43$, $p = .215$, $\eta^2_p = .044$.

The ANOVA for bin 3 did not reveal a main effect of target type, $F(1, 31) < 1$, $p = 585.$, $\eta^2_p = .01$, a main effect of block, $F(5, 155) = 1.28$, $p = .276$, $\eta^2_p = .04$, or an interaction between target type and block,

$F(5, 155) = 1.28$, $p = .275$, $\eta^2_p = .04$. Taken together these results suggest the guidance provided by an invariable target is the same as a variable target.

3.2.2.4 Summary. The durability hypothesis was partially supported by the results. The invariable target showed learning with bin 1 and bin 2 improving from block 1 to block 6 with RT. Bins 1, 2, and 3 improved from block 1 to block 6 with search initiation. Both bin 1 RT did not differ between the invariable target and variable target for the later blocks (2, 3, 4, 5, and 6). The invariable target was slower than the variable target in bin 1 of block 1 for RT. This result suggests VWM is required before the invariable template can guide from LTM.

3.2.3 CONSISTENT MAPPING HYPOTHESIS. The consistent mapping hypothesis predicts a LTM template does not require reactivation in VWM. To test the consistent mapping hypothesis the invariable target blocks from the invariable target color distractor condition and non-target color distractors condition were compared. In the non-target color distractor condition, the invariable target is only ever a target and therefore, the relationship between the target and the color is strong. In the invariable target color distractor condition, the invariable target color appears as a target and a distractor making the relationship between the target and the color weaker. Dependent measures from bins 1, 2, and 3 were submitted to separate 2 x 6 mixed factor ANOVAs with condition (invariable target color distractor, non-target color distractors) and block (1-6).

3.2.3.1 Response Time. The consistent mapping hypothesis predicts faster bin 1 response times in the later blocks for invariable target color distractor condition. The ANOVA did not reveal a main effect of condition, $F(1, 62) = 1.66$, $p = .202$, $\eta^2_p = .026$. The ANOVA revealed a main effect of block, $F(3.03, 188.07) = 4.23$, $p = .006$, $\eta^2_p = .064$, and a significant interaction between block and condition, $F(3.03, 188.67) = 3.02$, $p = .03$, $\eta^2_p = .046$. The interaction was caused by the non-target color distractors condition bin 1 in block 1 being slower than the invariable target color distractor condition block 1 (Table 13). The remaining blocks did not differ between the non-target color distractors and the invariable target color distractor conditions. The non-target color distractor condition bin 1 in block 6 ($M = 1056.80$ ms) was faster than bin 1 in block 1

(*M* = 1372.15 ms), *t*(31) = 5.99, $p < .001$. The invariable target color distractor condition bin 1 in block 6 (*M* = 1069.90 ms) did not differ from bin 1 in block 1 (*M* = 1049.54 ms), *t*(31) = -.179, $p = .859$.

Table 13.
RT for bin 1 by block.

		Block					
Bin	Target type	1	2	3	4	5	6
1	Non-target color	1372.15 *	1230.43	1182.09	1059.62	1105.91	1056.80
	Invariable target color	1049.54 *	1137.72	1100.27	1000.33	1084.77	1069.90

* $p < .008$ Bonferroni correction

The consistent mapping hypothesis predicts faster bin 2 response times in the later blocks for invariable target color distractor condition. The ANOVA revealed a main effect of block, $F(3.8, 235.63) = 7.21$, $p < .001$, $\eta^2_p = .104$. The ANOVA did not reveal a main effect of condition, $F(1, 62) < 1$, $p = .683$, $\eta^2_p = .003$, or an interaction between condition and block, $F(3.8, 235.63) = 1.79$, $p = .135$, $\eta^2_p = .028$.

The ANOVA for bin 3 revealed a main effect of block, $F(3.34, 207.38) = 4$, $p = .006$, $\eta^2_p = .061$. The ANOVA did not reveal a main effect of condition, $F(1, 62) = 1.57$, $p = .215$, $\eta^2_p = .025$, or an interaction between block and condition, $F(3.34, 207.38) = 1.13$, $p = .340$, $\eta^2_p = .018$.

3.2.3.2 Search Initiation. The consistent mapping hypothesis predicts faster bin 1 search initiation in the later blocks for invariable target color distractor condition. The ANOVA did not reveal a main effect of condition, $F(1, 62) < 1$, $p = .590$, $\eta^2_p = .005$. The ANOVA revealed a main effect of block, $F(3.32, 205.86) = 6.99$, $p < .001$, $\eta^2_p = .101$, and a significant interaction between block and condition, $F(3.32, 205.86) = 2.94$, $p = .03$, $\eta^2_p = .045$. The interaction was caused by the non-target color distractor condition bin 1 in block 1 was slower to initiate than the invariable target color distractor condition bin 1 in block 1. The non-target color distractor bin 1 in block 1 (*M* = 208.19 ms) was slower to initiate than bin 1 in block 6 (*M* = 161.67 ms), *t*(31) = 4.16, $p < .001$. The invariable target color distractor bin 1 in block 1 (*M* = 180.95 ms) did not differ from bin 1 in block 6 (*M* = 164.65 ms), *t*(31) = 1.35, $p = .188$.

The consistent mapping hypothesis predicts faster bin 2 search initiation in the later blocks for invariable target color distractor condition. The ANOVA did not reveal a main effect of condition, $F(1, 62) < 1$, $p = .477$, $\eta^2_p = .008$. The ANOVA revealed a main effect of block, $F(3.71, 230.45) = 9.49$, $p < .001$, $\eta^2_p = .133$, and an interaction between block and condition, $F(3.71, 230.45) = 2.55$, $p = .044$, $\eta^2_p = .04$. The non-target color distractor condition initiated search faster in bin 2 in block 6 (M = 159.97 ms) compared to bin 2 in block 1 (M = 195.21 ms), $t(31) = 6.51$, $p < .001$. The invariable target color distractor condition also initiated search faster in bin 2 in block 6 (M = 160.18 ms) than bin 2 in block 1 (M = 186.46 ms), $t(31) = 3.1$, $p = .004$. Search initiation did not differ between the non-target color distractor condition and the invariable target color distractor condition at any of the blocks (Table 14).

The ANOVA for bin 3 revealed a main effect of block, $F(3.91, 242.34) = 4.53$, $p = .002$, $\eta^2_p = .068$. The ANOVA did not reveal a main effect of condition, $F(1, 62) < 1$, $p = .543$, $\eta^2_p = .006$, or an interaction between block and condition, $F(3.91, 242.34) = 1.38$, $p = .243$, $\eta^2_p = .022$.

Table 14.
Search Initiation for bins 1 and 2 by block.

		Block					
Bin	Target type	1	2	3	4	5	6
1	Non-target color	208.19 *	180.25	165.99	175.69	158.94	161.67
	Invariable target color	180.95 *	176.62	172.06	158.99	172.57	164.65
2	Non-target color	195.21	160.39	155.80	156.13	158.06	159.97
	Invariable target color	186.46	153.19	180.05	164.87	171.97	160.18

* $p < .008$ Bonferroni correction

3.2.3.3 Navigation. The consistent mapping hypothesis predicts faster bin 1 navigation in the later blocks for invariable target color distractor condition. The ANOVA did not reveal a main effect of block, $F(4.42, 274.18) = 1.41$, $p = .228$, $\eta^2_p = .022$, a main effect of condition, $F(1, 62) < 1$, $p = .564$, $\eta^2_p = .005$, or an interaction between block and condition, $F(4.42, 274.18) < 1$, $p = .474$, $\eta^2_p = .014$.

The ANOVA for bin 2 did not reveal a main effect of block, $F(4.26, 264.08) < 1$, $p = .751$, $\eta^2_p = .008$, a main effect of condition, $F(1, 62) < 1$, $p = .538$, $\eta^2_p = .006$, or an interaction between block and condition $F(4.26, 264.08) < 1$, $p = .772$, $\eta^2_p = .007$.

The ANOVA for bin 3 did not reveal a main effect of block, $F(3.85, 238.91) = 1.49$, $p = .206$, $\eta^2_p = .024$, a main effect of condition, $F(1, 62) = 1.07$, $p = .306$, $\eta^2_p = .017$, or an interaction between block and condition, $F(3.85, 239.91) = 1.53$, $p = .197$, $\eta^2_p = .024$.

3.2.3.4 Summary. The consistent mapping hypothesis was not supported by the results. Condition changed across blocks for bin 1 RT, bin 1 search initiation, and bin 2 search initiation. Follow-up tests only found a difference between the non-target color distractor and the invariable target color condition at block 1 for bin 2 with search initiation. This was caused by non-target color distractors condition being slower. These results suggest a weaker association between the target color and the target did not prevent learning of the target.

3.2.4 LTM RETRIEVAL HYPOTHESIS. The LTM retrieval hypothesis predicts future encounters with a LTM template automatically active previous episodes. When these previous episodes are not identity consistent, LTM retrieval hypothesis predicts a negative impact on performance. To test this hypothesis, the variable blocks from the non-target color distractors condition, invariable target color distractor condition, and the variable target color distractor condition were compared. Navigation was submitted to a 3 x 5 mixed factor ANOVA with distractor type (non-target color, invariable target color, variable target color) as a between subjects factor and bin as a within subjects factor. An ANOVA revealed no main effect of distractor type, $F(1, 93) = .466$, $p = .629$, $\eta^2_p = .010$, no main effect of bin, $F(4, 372) = .231$, $p = .921$, $\eta^2_p = .002$, and no significant interaction between target type and bin, $F(8, 372) = 1.281$, $p = .252$, $\eta^2_p = .027$. The presence of a distractor that had previously been a target did not negatively impact finding the target any more than the other distractors in the display.

In addition, fixation durations on the invariable target color distractor from the invariable target color distractor condition, the variable target color distractor from the variable target color distractor condition, and a non-target color distractor from the non-target color distractors condition were submitted to a one-way ANOVA. The interaction was not statistically significant, $F(2,95) = .903$, $p = .409$. When a target color distractor was fixated, the length of the fixation duration did not differ from a random distractor. These results suggest a future encounter with a previous target color does not necessarily cause retrieval of past instances.

3.3 DISCUSSION

Consistent with the LTM template hypothesis, Experiment 2 supports faster search performance for invariable targets compared to variable targets. In addition to overall performance, an invariable target leads to the faster establishment of an attentional template resulting in faster search initiation and an invariable target leads to a better mental representation used for comparison to potential targets and/or faster decision making. These findings are consistent with Experiment 1. Surprisingly, a significant interaction was found between target type and bin for navigation. The invariable targets became faster from bin 1 to bin 5. However, the invariable target performance was never better than the variable target at any of the bins. This shows the invariable target was learned across repetitions, but this learning did not necessarily improve guidance compared to the variable target.

Furthermore, Experiment 2 demonstrates that an attentional template is reactivated in VWM before LTM guides attention. Unlike Experiment 1, all the invariable blocks have the same target color and bin 1 consists of trials 1 through 4 collapsed across blocks. Yet, the invariable and variable targets did not differ at bin 1. This suggests it takes at least three trials for the attentional template to fully switch from VWM to LTM (Carlisle et al., 2011; Gunseli et al., 2014). Furthermore, search initiation differed between the invariable and variable targets for bin 1 in block 3. The invariable target was encountered for forty trials by block 3. This suggests behavioral changes appear with more trials with an invariable target than the change to the CDA amplitude.

There is support for the durability hypothesis. Experiment 1 found a difference between a VWM target and a LTM target around 18 to 20 trials. The number of trials in Experiment 2 was reduced to the number where the two templates begin to differ for verification (20 trials). A block analysis with all the trials it takes to show a difference between a VWM template and a LTM template supports learning for both types of targets from block 1 to block 6. However, the learning is larger for the LTM target than the VWM target suggesting the LTM target is more durable than a VWM template. This suggests the reemergence of VWM in the early bins following a delay does not necessarily mean the LTM target has to be learned again.

The findings of Experiment 2 did not support the consistent mapping hypothesis. The invariable target from the non-target color distractor condition was slower to learn in block 1 than the invariable target from the invariable target color distractor condition. At the later blocks the two invariable targets did not differ in performance. Unlike Carlisle et al. (2011) the repetition runs with the invariable targets were longer and only one invariable target was learned throughout the experiment. This may have benefited the invariable target color distractor condition. Learning may have been stronger after 20 trials than 7 trials.

The findings of Experiment 2 did not support the LTM retrieval hypothesis. A distractor that shared the invariable target color did not disrupt performance in the variable target blocks. This could be due to how information in VWM and LTM is prioritized. VWM may only have one item in the focus of attention or be able to prioritize one item at a time (Olivers, 2009; Olivers, et al., 2011; van Moorselaar, et al., 2014). A LTM template could free up resources in VWM and prioritize in VWM. A single irrelevant item in VWM can be prioritized when a LTM template is used to guide attention during a visual search task (Gunseli et al., 2016). A distractor that matches the item in VWM causes interference during search with a LTM template on the second repetition trial. The LTM template might have still been activated during the VWM target blocks, but the VWM target could have had higher prioritization being the only item in VWM. This higher prioritization might have prevented interference from the invariable target color distractor.

CHAPTER 4. GENERAL DISCUSSION

Overall, the results of this study support the transfer of an attentional template to LTM, which results in better performance compared to a changing attentional template in VWM (Experiments 1 & 2). Better performance can be attributed to faster search initiation (Experiment 1 & 2) as demonstrated by shorter first fixation durations. Better performance can also be attributed to faster verification of the target (Experiment 1 & 2) as demonstrated by shorter fixation durations on distractors (Experiment 1 & 2) and responses (Experiment 1 & 2). More importantly, the separation in behavior between a consistent target and a changing target appears at different points based on the process. The separation in search initiation appears to happen as early as three to four trials (Experiment 1 & Experiment 2). The separation in verification appears to happen as early 18 - 20 trials (Experiment 1 & Experiment 2). Interestingly, this transfer from VWM to LTM occurs regardless of whether the target is encountered again (Experiment 2).

Transferring a template from VWM to LTM is not immediately reflected in behavioral performance when compared to a variable target. Previous research did find a change in RT that accompanied the change in the CDA amplitude, but did not find a difference in RT when comparing an invariable to variable target (Carlisle et al., 2011). The results of this study suggest that behavioral changes do not appear until around 20 trials with the invariable target compared to a variable target. The emergence of a difference in RT and verification is consistent with learning occurring within the first 10 to 20 trials of a task (Newell & Rosenbloom, 1981). These findings lead to the bigger question of why a neural change would occur before a behavioral change. One possibility is the CDA reflects the creation and retrieval of the memory and behavioral performance reflects the retrieval and use of the memory. The change in CDA amplitude is not instantaneous, it occurs over 3 to 7 trials. In previous ERP research (Carlisle et al., 2011; Gunseli et al., 2014) and the present study, the encoding time for the target cue is brief (100 to 200 ms). Brief encoding times are used as a way to ensure that information is in VWM and not LTM. Yet, consistent practice with a task allows for information to be transferred to LTM (Gunseli et al., 2014; Logan, 1988, 2002; Reinhart et al., 2014). This suggests it takes less time to transfer information to LTM in situations with consistent practice. The consistent practice may speed the transfer of the target to LTM, but this does not necessarily mean the target has been established as a strong retrieval cue. Instance theory predicts that automatization occurs as the number of instances increases.

Instance theory predicts an accumulation of memories in LTM that are available for retrieval. P1 is a positive waveform that becomes more negative as the number of instances with a stimulus increases and has been associated with recognition based on familiarity (Reinhart & Woodman, 2014, 2015; Woodman et al., 2013). In addition, P1 has been shown to become more negative as the CDA amplitude disappears (Woodman et al., 2013). Together, the change in P1 and the CDA suggests the passing of the attentional template with the CDA amplitude decreasing as the contents shift and P1 increasing with more experience. More importantly, the P1 negativity increases over repetitions, however, this is based upon seven repetitions. Future research should monitor the change in CDA, PI, and RTs with more repetitions of the target. Both the CDA amplitude and the RT change as the number of repetitions increase, but the difference in the RTs between the invariable target and variable target could directly reflect the change in P1. As the P1 shows better recognition of an invariable target, P1 might reflect the strength of retrieval.

The change in behavioral performance is not due to a change in the attentional template's function to bias attention in the visual environment. This finding has been shown in previous research with similar search slopes for invariable and variable targets (Woodman et al., 2007). Items held in VWM and LTM have similar precision (Brady, Konkle, Gill, Oliva, & Alvarez, 2013) and this suggests that information provided to lower level perceptual processes would be similar. The results of the present study support this by finding no difference in guidance between a VWM and a LTM template. The present findings suggest a LTM template provides a better memory representation to compare potential targets and/or improve decision making processes. The precision of VWM and LTM suggests that the quality of the representation used for comparison to potential targets would be the same between VWM and LTM. Future research should focus on how the similar precision between a VWM and LTM memory does not impact visual search differently.

The current results support the changes in performance with a LTM template correspond to the second function of an attentional template as a reference to compare potential targets against. In both Experiment 1 and

Experiment 2, verification became faster at 20 trials for an invariable target compared to a changing target. The attentional template was more effective as a comparison representation and/or in aiding decision making processes. Furthermore, an LTM template's search initiation and/or verification can be impacted by the contents of VWM (Woodman et al., 2001). Performing a visual search task with an invariable target when VWM is not produces a different search slope intercept than performing a visual search task with an invariable target when VWM is full. The current findings suggest search initiation and verification are what distinguish a LTM template from a VWM template. When an invariable target creates a LTM template remaining items in VWM can be prioritized when the items are task relevant (e.g. matches a distractor; Gunseli et al., 2016) This change in prioritization in VWM could account for the changes to the search slope intercept found in Woodman et al. (2001). The present study found better performance for a LTM template compared to a VWM, but the present study cannot address how VWM and LTM work together. Future research should focus on how VWM and LTM work together.

Previous research has shown the reappearance of VWM when an invariable target is encountered in the future (Carlisle et al., 2011; Gunseli, et al, 2014; Reinhart et al., 2014). VWM is engaged initially during the learning phase to create a LTM template and again with reencounters with the target VWM holds the attentional template for about three trials. This finding is counter to instance theory which predicts previous episodes to be retrieved faster resulting in the use of LTM with reencounters (Logan, 1988). With a LTM template it is postulated that the behavior is now more automatized. This automatization should allow LTM to influence behavior immediately. In Experiment 2, new encounters with the LTM template produced behavioral responses that did not differ from a VWM template for the first three trials of each block. This suggests reactivation in VWM occurs with new encounters of a LTM template. The reappearance of VWM might not be the relearning of the attentional template, but more of a necessarily step for task switching. A task switch might trigger than the task ahead might be novel and involve VWM to accomplish the task. Once the task is established through the retrieval of past instances then LTM would be used. In the present study, the reappearance of VWM did not prevent the behavioral performance from becoming faster across blocks. This suggests VWM reemerges, but VWM is not necessarily in control for long.

The results from the oculomotor measures offer another way to examine the passing of the attentional template from VWM to LTM. Consistently, the duration of the first fixation differed between an invariable target and a changing target. This difference occurred almost immediately in Experiment 1; however, the Experiment 1 bins contained six trials. In Experiment 2, the difference occurred at bin 2 which contained four trials (trials 5, 6, 7, 8). The CDA amplitude is found to decrease by three trials and to be nearly absent by seven trials (Carlisle et al., 2011; Gunseli, et al, 2014; Reinhart et al., 2014). Recently, Gunseli et al. (2016) has shown interference from memory cues held in VWM during a dual task in as little as two trials when a search target is repeated. The first fixation duration may be a way to index the passing of the attentional template without a CDA or a dual task. Future research should combine eye tracking and ERPs and eye tracking and a dual task to investigate this connection.

Previous research suggests that an attentional template requires time to be established and to be effective for guiding attention (Vickery et al., 2005; Wolfe et al., 2004). The results of the current study suggest the type of target impacts the template's readiness for use. A VWM template's performance was the same if the delay between the target cue and search array was 50 ms or 900 ms. A VWM template's performance did not differ from a LTM template's performance when there was 900 ms delay between the target cue and search array. More importantly, the effectiveness of the attentional template did not translate to changes in guidance. Search began sooner with an invariable target, but this did not lead to the target being found faster during navigation compared to a changing target. This suggests the information provided from a VWM and LTM template to heighten early visual processes is the same. However, search initiation and verification differed depending on whether the attentional template was stored in LTM or VWM.

The results of this study offer an understanding of how a LTM attentional template guides attention. Specifically, a LTM attentional template does not change guidance. Guidance is the same whether an attentional template is stored in VWM or LTM. Instead, a LTM attentional template results in quicker search initiation and faster verification of the target. Future research should focus on comparing a VWM attentional template and a LTM template as it relates to the comparison process to understand how verification is enhanced with a LTM template. This study suggests performance with a VWM and LTM attentional template does differ, but the transfer, exhibited by a change in CDA amplitude, starts with fewer exposures to the task than the appearance of behavioral changes, exhibited by oculomotor measures.

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APPENDIX: IRB APPROVAL

ACTION ON EXEMPTION APPROVAL REQUEST

LSU

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu | lsu.edu/irb

TO: Rebecca Goldstein
Psychology

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: August 28, 2015

RE: **IRB#** E9461

TITLE: Searching, Searching, Searching

New Protocol/Modification/Continuation: New Protocol

Review Date: 8/28/2015

Approved X **Disapproved** ______

Approval Date: 8/28/2015 **Approval Expiration Date:** 8/27/2018

Exemption Category/Paragraph: 2a

Signed Consent Waived?: No

Re-review frequency: (three years unless otherwise stated)

LSU Proposal Number (if applicable):

Protocol Matches Scope of Work in Grant proposal: (if applicable)

By: Dennis Landin, Chairman ______

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE:**

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

1. Study Title: Searching, Searching, Searching

2. Performance Site: Louisiana State University – Audubon Hall B5

3. Investigators: The following investigators are available for questions about this study,
M-F, 8:30 a.m. – 4:30 p.m. – Rebecca Goldstein 225-578-7792, rgolds5@lsu.edu
Melissa Beck, mbeck@lsu.edu

4. Purpose of the Study: The purpose of this research project is to investigate the relationship between memory and attention while conducting a visual search task for an indicated item.

5. Subject Inclusion: Individuals between the ages of 18 and 65, have normal or corrected to normal vision (i.e. glasses or contacts), and normal color vision (i.e. can see all colors). All of the inclusion criteria must be met to participate in this study.

6. Number of Subjects: 800

7. Study Procedures: The study will last for one session between 30 and 90 minutes. Participants will be provided with instructions regarding the task before eye tracker set-up. After eye tracker set-up, participants will search for the indicated item among varying displays.

8. Benefits: Subjects will receive course credit for participating in the study. Additionally, the study may yield valuable information about the relationship between attention and memory processes.

9. Risks: You will asked to sit in front of a camera and an invisible infrared light source that shines a weak spot of light on your retina. The amount of infrared light absorbed by your retina will be less than 7.5% of the suggested Maximum Permissible Exposure for continuous sources of infrared light given by Sliney and Freasier[1]. This level of light is comparable to what you would receive on a bright, sunny day.

10. Right to Refuse: Subjects may choose not to participate or to withdraw from the study at any time without penalty or loss of any benefit to which they might otherwise be entitled.

11. Privacy: Results of the study may be published, but no names or identifying information will be included in the publication. Subject identity will remain confidential unless disclosure is required by law.

12. Signatures:

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Dennis Landin, Institutional Review Board (225)-578-8692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.

Participant Signature: ______________________________ Date: ________________

[1]Sliney, D.H., & Freasier, B.C., Evaluation of optical radiation hazards. Applied Optics, 1973, 12, 1-24.

VITA

Rebecca R. Goldstein graduated with a Bachelor of Arts from Washington College in in May 2006. She proceeded to pursue psychology with a Master of Science from Villanova University in December 2008. Following a brief hiatus, Rebecca returned to psychology as a research assistant at Template University in August 2010 before starting the Cognitive and Brian Science program in the Department of Psychology at Louisiana State University in August 2011. She plans to graduate in August 2016.