4-2016

Effects of Post-cues on Visual Short- and Long-Term Memory

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by

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Submitted to the LSU Roger Hadfield Ogden Honors College in partial fulfillment of the Upper Division Honors Program.

April 2016

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Abstract

Change detection tasks have been thoroughly used to examine many aspects of visual short-term memory and long-term memory. Providing a cue to a specified item on a test image has been shown to access items stored in long-term memory and bring them forward to short-term memory for comparison purposes. The current study examined post-cue effects on famous and non-famous faces. We hypothesized that accuracy would be higher on trials that received the cue due to the activation in memory brought on by the cue. Performance should be especially high on cued trials with famous faces, due to the previous familiarity with these faces and solid LTM representations. Serial position was used to investigate a 2-state vs 3-state model. There was shown to be a main effect of famous faces, cue, and serial position. There was also an interaction between serial position and cue. However, no other interactions were found. A lack of power was very limiting for this study.

Effects of Post-cues on Visual Short- and Long-Term Memory

Imagine you and a friend are out shopping for your mother's birthday. You stop at a boutique and gaze around the store. When your eyes land on a table full of earrings, you know that your mother would love them. As you sort through them, you pick out a few that would be good options. Then your friend calls your name and you look up to see where she is. When you look back down, you can't remember which pair of earrings you had decided upon as your mother's gift. Not being able to remember certain items our attention has been taken away from is a constant struggle in our fast paced lives.

The debate over memory operations and structure has been going on for decades. While some believe that memory is only one system (Crowder, 1993), others have found that it is formed by two systems, short-term memory (STM) and long-term memory (LTM) (Cowan, 2001). A one-system explanation of memory claims that while holding information active for brief intervals of time is necessary, this process requires only a one-system memory. STM does exist but not in the sense of being a different system with different rules or processes for a short-term storage (Crowder, 1993). Alternatively, Cowan (2001) asserted that there are two distinct systems in memory. This is explained by his evidence of a pure chunk-based capacity limit in STM. Pure chunks are items that cannot be combined with other items to form a larger, higher-order chunk. The pure chunk-based capacity limit shows that there is a specialized mechanism in STM that does not exist in LTM, which has no capacity limit. He goes on to explain that these two systems interact with each other when higher-order chunking is not suppressed. Concepts in LTM help to form chunks held in STM and then build up the information in these chunks. While there is still the same amount of chunks, LTM aids in increasing the size of chunks, and therefore being able to hold more information active in STM (Cowan, 2001).

More recent research has been shown to support a two-system memory and examines how information is transferred between STM and LTM. It appears that there are multiple states in memory and these states differ in their levels of accessibility when information needs to be retrieved and brought into focus. One theory suggests a 2-state model of memory consisting of STM and all past representations in LTM (Cowan, 2001; McElree, 2006; McElree & Dosher, 1989). Cowan (2001) concluded that chunks are formed in STM with the help of LTM by a source of information that is highly accessible but just outside of the focus of attention (FOA). When this information is activated it is deemed relevant and can be retrieved easier if needed. LTM is unlimited in capacity, but the contents are not active unless they are retrieved into FOA. The 2-state model prediction of a difference of accessibility between FOA (or STM) and LTM was also supported by McElree and Dosher (1989) and McElree (2006), but with a different capacity limit. They found that information could be accessed at a faster rate if it was the last item viewed, and items viewed in past positions were all accessed at a slower rate. This indicates that information in FOA is accessed faster because it is more active than passive representations in LTM. Although there is support for a 2-state model of memory, evidence has also emerged in favor of a 3-state model of STM.

As evidence of a two-system memory developed, there were conflicting views as to what was considered the focus of attention and its capacity limit. Given this ambiguity, Oberauer (2002) outlined a 3-state model of STM. This model claimed that both versions of the FOA in previous research exist and were actually two different functional states in STM, along with a third state where information was not active but could be recalled for later use. These three states are the focus of attention, direct access region (DAR), and activated long-term memory (aLTM). The FOA is for immediate processing and can bring forward any one item from the DAR and use it for any cognitive operation necessary. The DAR is the selection set of items that is capacity limited and holds information active for future processing. Information in aLTM is kept passively in the background, but can still be readily used for ongoing cognition if retrieved. [This model was supported by evidence found using a memory-updating task involving two lists of numbers. In the first condition, one set was deemed an active set and the other a passive set. The active set was updated by arithmetic and the passive set had to be remembered for recall. The other condition included two active sets. It was found that reaction times (RT's) were faster in the first condition, showing that information in aLTM does not interfere with ongoing cognition. Also, when an active set was large, RT's were longer because switching between multiple objects in DAR takes more time. Finally, when an item was currently in FOA and was selected again, this update was accomplished several milliseconds quicker than if a new item from DAR must be selected.]

To further support the claim of a 3-state model, Nee and Jonides (2013) used fMRI to examine visual STM and found a triple dissociation in the brain; three qualitatively different areas in the brain mediate access to the three states in STM. It was shown that the inferior parietal cortex facilitates the FOA. The medial temporal lobe facilitates the DAR and finally, the left ventrolateral prefrontal cortex facilitates access to the aLTM. These results are in line with support for a 3-state model of memory for verbal STM. It was concluded that under both contexts, STM memory was accessed in the same areas in the brain; therefore, the three states of memory are domain general (Nee & Jonides, 2013).

A different area of examination in visual STM is how much detail is actually stored in our memories. There has been much research investigating a phenomenon called 'change blindness'. Simons and Levin's (1997) review of change blindness defines it as "our inability to detect changes to objects or scenes from one view to the next". Change detection is an active search process where items are attended, encoded, and then compared. There are many theories as to why people are sometimes found to be unobservant of changes, but it is suggested that too much information would overload the visual system and result in confusion. Instead our visual system takes the gist of a scene, rather than encoding many rich details. Therefore, changes will not be detected unless the gist of the scene changes.

Hollingworth and Henderson (2002) challenged this conclusion by examining change blindness in natural scenes. This study revealed changes in objects could be detected without the whole scene changing. Changes were detected when objects were replaced with similar objects and when objects were rotated. These changes were identified after the eyes had fixated on a new point, showing that changes outside of FOA could be noticed. Another major finding was that information is moved into LTM after focus shifts, aiding the change detection process. They suspected several reasons for past evidence of severe change blindness: 1) the change could occur before the item was fixated, 2) information from the target object is not properly retrieved and therefore compared accurately, and 3) some change detection tasks may be incorrect in claiming that if a change is not explicitly detected then the relevant information was not stored in visual memory. It was concluded that attending creates a stable higher-order visual representation in memory that are retained after the withdrawal of attention.

The properties of STM in relation to change blindness have been studied with many different types of change detection tasks. In another common change detection task, a study image appears and is examined by the participant. Then after a brief interstimulus interval (ISI) a test image appears and participants indicate if a change has occurred in the image or not (Rensink, 2002). When testing for the 3-state model, the order in which the items are encoded during the task is important because the order is thought to correspond to where the item is in STM: FOA, DAR, or aLTM (Oberauer, 2002; Nee & Jonides, 2013). That is, as each item is attended and encoded, the serial positions of the items are created for the trial. For example, the most recent item encoded is in the FOA; the previous 2-3 items are in DAR and the items encoded before that are in aLTM. After the items are viewed, a blank screen or a mask replaces the study image. On a change trial the test image appears and one of the items has changed. This changed item corresponds to one of the serial positions in STM. For a no-change trial, all of the items will appear exactly the same as the study image. Importantly, performance is examined based on the serial position during encoding to test for different states of STM.

The different states of STM vary in their degree of accessibility or how readily available the representation is for the comparison process that is necessary for change detection to occur. Accurate change detection depends on attending to the post-change object and comparing it to the representation of the pre-change object (Beck & van Lamsweerde, 2010; Hollingworth & Henderson, 2002; Hollingworth, 2003). Therefore, one methodological difference that could potentially influence performance is the type of test-array. In some studies the test image is presented with the same amount of items as the study image. This requires the participants to determine if any of the items have changed. Therefore, a comparison process must be carried out for each item until a change is detected or all items have been compared (Hollingworth & Henderson, 2002).

Conversely, some studies present only one item in the test image or present a cue pointing to one item that needs to be compared (Beck & van Lamsweerde, 2010; Hollingworth, 2003; Luck & Vogel, 1997). Therefore, those who receive a cue will be asked if the specified item has changed, while those without a cue will be asked if any of the items have changed. It is thought that since the cue is presented after encoding, it aids in retrieving representations from LTM (Beck & van Lamsweerde, 2010; Hollingworth, 2003). Beck and van Lamsweerde (2010) refer to this as the LTM retrieval hypothesis. It was shown that when a post-cue was available, changes could be detected even when the number of items exceeded the capacity of STM. From this it was concluded that past change detection tasks have underestimated the total amount of information that is encoded from the study image. Successful change detection relies on adequate encoding, retention, retrieval, and comparison of visual representations. For retrieval to occur, a certain level of activation must be reached. In their study, it was shown that information could be made available to the STM from aLTM when proper retrieval cues are given.

However, some studies have not found a post-cue effect (Landman, Spekreijse & Lamme, 2003; Luck & Vogel, 1997). Landman et al. (2003) showed that the cue was effective when presented during the ISI between the study image and the test image, but was shown to be ineffective in improving change detection when shown with the test image. They theorized that the representations of the study image might have been overwritten by the test images, leading to lower accuracy. The authors suggest that the type of stimuli used may play a role in accurate change detection. The abstract stimuli used in the change detection possibly make it more difficult to develop higher-level representation, and therefore comparisons are not as accurate.

The situations under which post-cue effects are found and when they are not found may depend on the likelihood that LTM representations or aLTM representations were stored for the study stimuli. Beck and van Lamsweerde (2010) examined change detection performance and the use of cues to draw attention to the post-change item and examined the conditions that support a post-cue effect. Their results showed that when participants had significant time to encode the items in the study image, a post-cue effect was found across three experiments. It is thought that using meaningful stimuli is more likely to lead to a LTM representation. Unlike Landman et al. (2003) and Luck and Vogel (1997), Beck and van Lamsweerde (2010) used real world items that were easily recognizable. Post-cue change detection accuracy increased and the number of items monitored improved as well. It was shown that accuracy was improved for the cue trials even when the number of items exceeded the capacity of STM (7-10 items) suggesting that a cue will allow 1-2 more items to be held in aLTM and retrieved to STM for comparison purposes. Beck and van Lamsweerde (2010) study supports the LTM retrieval hypothesis and suggests that while monitoring visual stimuli, retrieval from LTM into STM is not automatic.

Previous research may be mixed on the role of LTM in maintaining information in STM because of the type of stimuli used across studies. As mentioned before, studies have not found post-cue effects when simplistic stimuli that repeated frequently across trials were used (Landman et al, 2003; Luck & Vogel, 1997), while other studies that used real world objects did find post-cue effects (Beck & van Lamsweerde, 2010; Hollingworth, 2003). This difference could be due to the type of stimuli. No post-cue effect was found when the stimuli being tested were considered simplistic, such as rectangular figures or different colored squares (Landman et al. 2003; Luck & Vogel, 1997). Landman et al. (2003) suggested that no effect was found because the study image was overwritten by the test image, while Luck and Vogel (1997) claimed that accuracy on change detection must not be limited by the decision process. Other research has shown that change blindness is less likely when the stimuli used are meaningful, like a natural scene or nameable objects (Beck & vanLamsweerde, 2010; Hollingworth & Henderson, 2002; Hollingworth, 2003). Therefore, stimuli that are highly familiar and complex may be particularly suited for demonstrating the role of LTM in aiding STM during change detection.

The possibility of information being transferred from STM to LTM and available for later activation, given the correct retrieval cues are present, is not necessarily without controversy. For example, there has been ongoing debate on whether representations in STM fade with gradual decay or terminate after a given amount of time (referred to as the sudden death hypothesis). Zhang and Luck (2009) suggested that STM appears to be an active, feedback driven system where all-or-none processes occur. They examined this by separately measuring the precision of the memory representation and the probability that the memory continued to exist. This was done by a short-term recall task where a participant was presented with three different colored squares. Then one item was cued and the participant reported the color on a color wheel. If the color reported was near the original color, then this memory was said to be precise. If the memory were terminated, the precision would be at chance. They discovered that the colors of squares could be held in STM for about 4 seconds while not losing either quantity or quality. After 4 seconds, the precision of the item does not decrease, however, the probability that it will be held in memory does decrease. This suggests that many higher-level brain activities operate on a threshold, when above the threshold the memory is active, and when below the threshold the memory is lost in an all-or-none fashion. However, it is possible that some part of the memory gradually declines and then disappears once a threshold is reached. This is similar to a computer crashing after gradually heating up. According to Zhang and Luck's (2009) sudden death hypothesis, the memory is lost altogether. An alternative hypothesis is that STM memories are transferred out of STM and into LTM or aLTM.

Souza and Oberauer (2014) investigated an alternate hypothesis of what causes retrieval failure of memories. They examined whether memories are forgotten by decay or interference. When considering interference, time serves as a retrieval cue. If two similar events occurred in a close proximity, the overlap will cause interference in the retrieval of target information. The results showed that forgetting was based on the relative spacing of trials, and their distinctiveness from each other in time. The further spread out the trials are, the less chance the participants will have of confusing them. They report that memory will be less likely to be recalled as time goes on, which is in agreement with Zhang and Luck (2009). However, they suggest that interference and the overlapping of memories cause this, rather than the overlap causing the sudden death of a memory. In change detection tasks, the events of attending to stimuli happen within a very close proximity. Providing a cue is thought to separate the target information from the interference and aid in the retrieval of representations from LTM so that they are brought into STM and used to make a decision.

In the current study we examined the role of LTM in STM by varying the degree to which the stimuli are linked to LTM representations. Specifically we chose to use famous and non-famous faces. Jackson and Raymond (2008) used upright faces of famous and non-famous people and examined whether famous faces would enhance the STM capacity because of the engrained traces in LTM. It is thought that the familiarity effect will activate the representations in LTM and bring them to STM for comparison. They suggest that the familiarity of faces strengthens the STM by enhancing the way features and configurations are integrated into memory, and that this information has better quality and quantity for encoding and retrieving. They also note that famous faces might be considered less complex stimuli than unfamiliar faces at a perceptual or conceptual level, as only a small amount of information is needed to identify them because of the thousands of previous exposures. Therefore, these images are easier to place into the limited amount of chunks available.

The current study aims to investigate the effects of a post-cue on change detection performance for famous and non-famous faces in six different serial positions. Half of the participants were randomly assigned to receive a post-cue. If the 3-state model is to be supported, the accuracy on the change detection task with post-cues should be higher on the more recently viewed items. It should be lowest on the items in the lag 5 and 6 as these positions are stored in aLTM, but because of the post-cue, they have a better possibility of being retrieved and brought to the FOA for a more accurate decision. Predicted results are shown in Figure 2. Accuracy overall is predicted to be higher on the famous faces compared to the non-famous faces due to the familiarity effect. This is because these faces are more likely to be represented in LTM and it would take less effort to make a comparison decision. It is also possible that LTM is helping increase the amount of representations that can be maintained in STM.

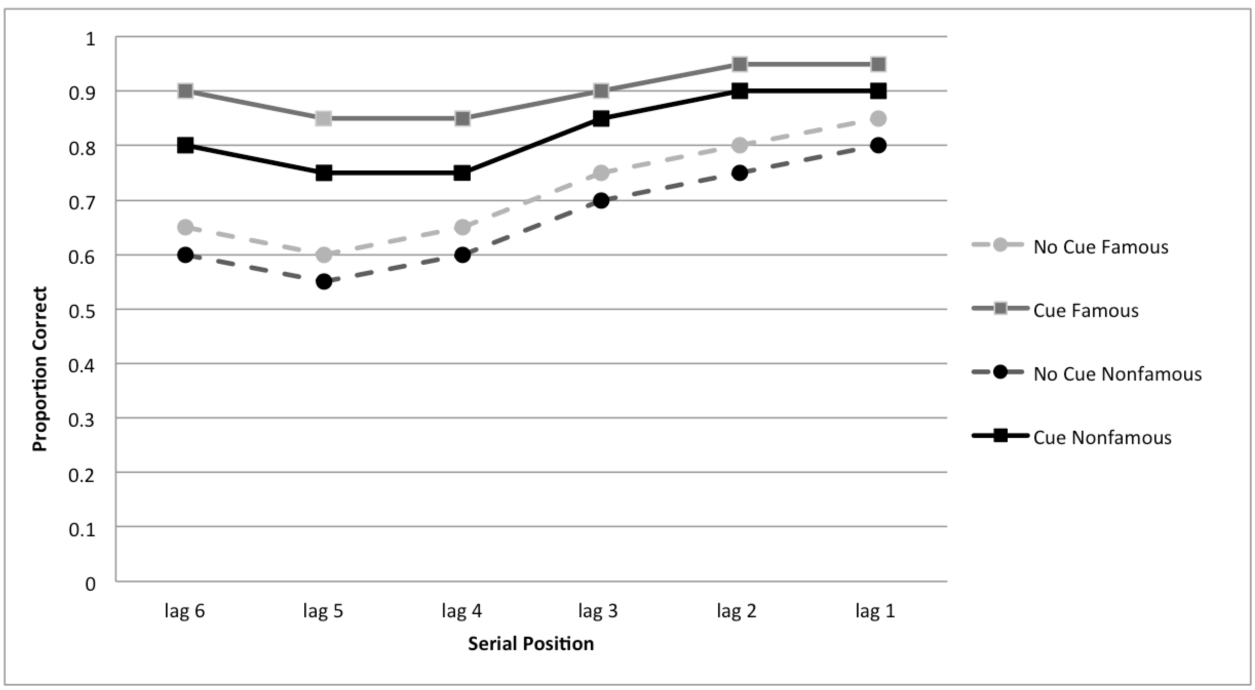

Figure 2. Our prediction is that the cue will aid in reaching the level of activation necessary to pull information out of aLTM, especially for the famous faces.

Methods

Participants

The participants for this experiment were recruited from Louisiana State University in Baton Rouge. We had a total of 34 adults. If accuracy for verbal load, famous change trials, or nonfamous change trials fell two standard deviations at or below average accuracy, the participant was excluded. Two participants from each condition were excluded leaving 30 participants (22 females; ages 18-23; mean age =20.5 years old. Half of the participants received a post-cue and the other half did not (n1 = 15, n2 = 15). Informed consent was obtained for all participants in accordance with the Institutional Review Board at Louisiana State University. Most were given extra credit for their participation and some were volunteers. All participants had normal or corrected-to-normal vision.

Design

The current experiment involved a 6 x 2 x 2 mixed-subjects design with serial position (6 positions) and familiarity (famous/non-famous) as within subjects independent variables, and cue (post-cue/no cue) as a between subjects independent variable. The dependent variable is accuracy on the change trials of the change detection task and was used to measure the strength of the cueing effect (post-cue/no cue) across levels of familiarity and across levels of serial position.

Materials

An Eye Link 1000 was used to track participants' eye movements during the task. The Experimenter builder and Data Viewer software that accompanies the Eye Link eye tracker was used to present the experiment, record the responses and organize the eye movement data. The stimuli set was made of 126 famous faces and 126 non-famous faces. The famous faces were obtained through a Google search. They were all facing forward with a smiling expression. The pictures were photoshopped to remove the background information and made to be 250 pixels tall. The nonfamous faces came from previous databases from Minear and Park (2004) and Vieira, Bottino, Laurentini, and De Simone (2013). These were photoshopped the same as the famous faces. The famous faces were rated by a separate group of participants to ensure that they were familiar. From this the 126 faces with the highest ratings were chosen. They were 51% female and 49% male. The racial make-up was 52% Caucasian, 32% African-American, 10% Hispanic, and 6% Asian. The non-famous faces matched these demographics.

The six faces that appeared in each trial were hardcoded into the program in a spreadsheet. They were placed into a random generator and then placed in the spreadsheet so that a face would not appear in the same position on a different trial. Therefore, each participant would see the same array for a given trial, but was free to choose the order the faces were encoded. Each face was shown approximately four times across all trials. However, for change trials the study face was replaced with a different face, which led to more repetitions for replacement faces. The replacement faces were hardcoded to replace the change face with a randomly selected different face of the same gender and race. A replacement face could not be a face that was already in the study image. The order of the trials was randomized for each participant.

The six faces were arranged in a circle, as depicted in Figure 1. Half of the participants received the stimuli with famous faces first and the non-famous second and vice versa. There were 168 trials, 84 for familiar faces and 84 for non-familiar faces. Each of the six serial positions had seven trials where a face is changed and seven trials with no change. Half of the participants received a post-cue of a green dot beside a face on the test image, and were asked, "Did this face change?" Half of the participants did not receive a cue and were asked, "Did any of the faces change?" Participants were alternated between the cue and no cue group, given the order they signed up for the experiment.

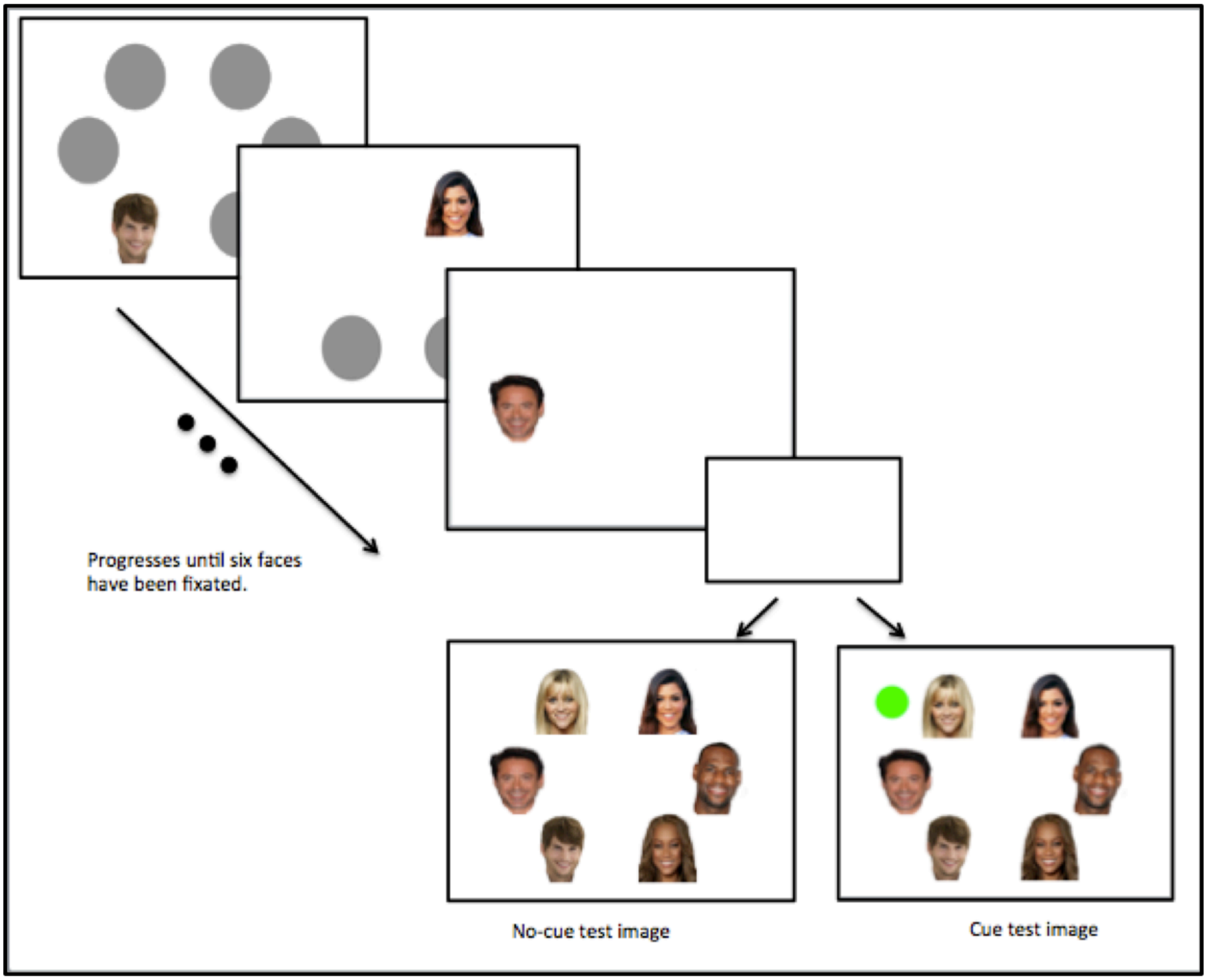

Figure 1. An example of the progression of the change detection task including a no post-cue and post-cue test image. Test image will remain on screen until a key is pressed indicating whether a change occurred or not.

Procedure

Participants completed two blocks of 168 change detection trials. Breaks were taken after trial 42, 84, and 127, to prevent fatigue. The experiment took approximately 1.5 – 2 hours to complete. Participants were tested individually. Prior to the experiment, voluntary consent was obtained and a demographic sheet was filled out. After a test for eye dominance participants were seated in front of the computer display at a viewing distance of ~53 cm. They placed their chin into the chinrest and stayed in this position except during breaks. They were then informed that they would view an array of faces and were required to determine if a change had occurred or not. At the beginning of each trial, they fixated on a dot in the middle of the screen and press the white button of a button box at the same time. This is a drift correct and helps to keep the eye tracker calibrated across trials. Participants were then instructed to repeat a random string of three digits during each trial to prevent verbal encoding of the faces. The white button was pressed to advance to the next screen. This string was randomized for each trial.

On each trial, the study array was presented with six faces. A grey oval marked the location of each face. When the grey oval was fixated, the face appeared. After the eyes moved away from the face, the face disappeared. Prior to the experiment the participants were informed that each face could only be looked at once and would then disappear. The study image was examined until all six faces were fixated. Next, a 1000 ms blank screen was presented. Then the faces were brought back up with the identity of one face either changed or not changed. For participants who received the post-cue, they were asked, “Did this face change?” The participants who do not receive a cue were asked, “Did any of the faces change?” Participants were given unlimited time to examine the faces and to respond after fixating all six faces. Participants responded by clicking the green button to answer “yes” and the red button to answer “no”. There were four practice trials at the beginning of the experiment that was comprised of famous faces that scored low on the familiarity ratings. After the participants had complete the task they were debriefed. Two participants were run in a room with different lighting as a result of a technical difficulty.

Results

In this experiment performance was measured by accuracy on the change detection trials in the change detection task. We performed a 6 x 2 x 2 repeated measures ANOVA on the data with serial position (1,2,3,4,5,6) and familiarity (famous, nonfamous) as within subjects factors and post-cue (post-cue, no cue) as a between subjects factor (Figure 3). The overall accuracy of the verbal load was $M = 0.91$, $SD = 0.07$. As expected there was a main effect of familiarity indicating that accuracy was higher for famous faces ($M = 0.83$, $SD = 0.11$) than for nonfamous faces ($M = 0.75$, $SD = 0.13$), $F(1,28) = 15.86$, $p < 0.05$. Although not included in the ANOVA analysis, it was shown that accuracy was also higher on no-change trials for famous faces ($M = 0.87$, $SD = 0.16$) than nonfamous faces ($M = 0.81$, $SD = 0.16$). These findings are in agreement with Jackson and Raymond (2008) who also found an effect of face familiarity.

There was a main effect of serial position showing that accuracy was significantly higher on at least one of the lags compared to the others, $F(5,140) = 5.8$, $p < 0.05$. There was also a significant effect of the post-cue which increased accuracy in the post-cue condition ($M = 0.83$, $SD = 0.11$) versus the no cue condition ($M = 0.74$, $SD = 0.13$), $F(1,28) = 4.8$, $p < 0.05$. Again, no change trials were not included in the ANOVA analysis but it was found that the post-cue effect was also stronger on the no change trials ($M = 0.93$, $SD = 0.05$) than the no cue no change trials ($M = 0.74$, $SD = 0.17$)

We also found was an interaction between serial position and post-cue showing that the cue had a higher effect on some lags versus others, $F(5,140) = 2.58$, $p < 0.05$. A Bonferroni post hoc test revealed serial position 1 was significantly higher than serial position 3 ($p < 0.05$), serial position 4 ($p < 0.05$), serial position 5 ($p < 0.05$), and serial position 6 ($p < 0.05$). However the 3-way interaction that was anticipated was not found, $F(5,140) = 0.36$, $p = 0.87$. All other interactions were found to be nonsignificant.

To further analyze the data we compared accuracy in STM to accuracy for LTM. We performed a 2 x 2 x 2 repeated measures ANOVA on the data. With serial position being changed to memory type. STM was comprised of lags 1, 2 and 3, while LTM was made from lags 4, 5, and 6. The same effects were found in the second analysis. There was a main effect of familiarity ($F(1,28) = 15.86$, $p < 0.05$), a main effect for type of memory ($F(1,28) = 10.95$, $p < 0.05$), and a main effect of post-cue ($F(1,28) = 4.8$, $p < 0.05$). When comparing the lags from STM to lags in LTM in the post-cue and no cue conditions, there was not a significant interaction, $F(1,28) = 3.28$, $p = 0.08$. However, this interaction is approaching significance and with more power, would hopefully fall below 0.05. When future participants are added to the experiment, this can be determined. As in the previous analysis the 3-way interaction was not significant, $F(1,28) = 0.28$, $p = .60$. Although this is still nonsignificant, the p-value was lowered. All other interactions were found to be nonsignificant.

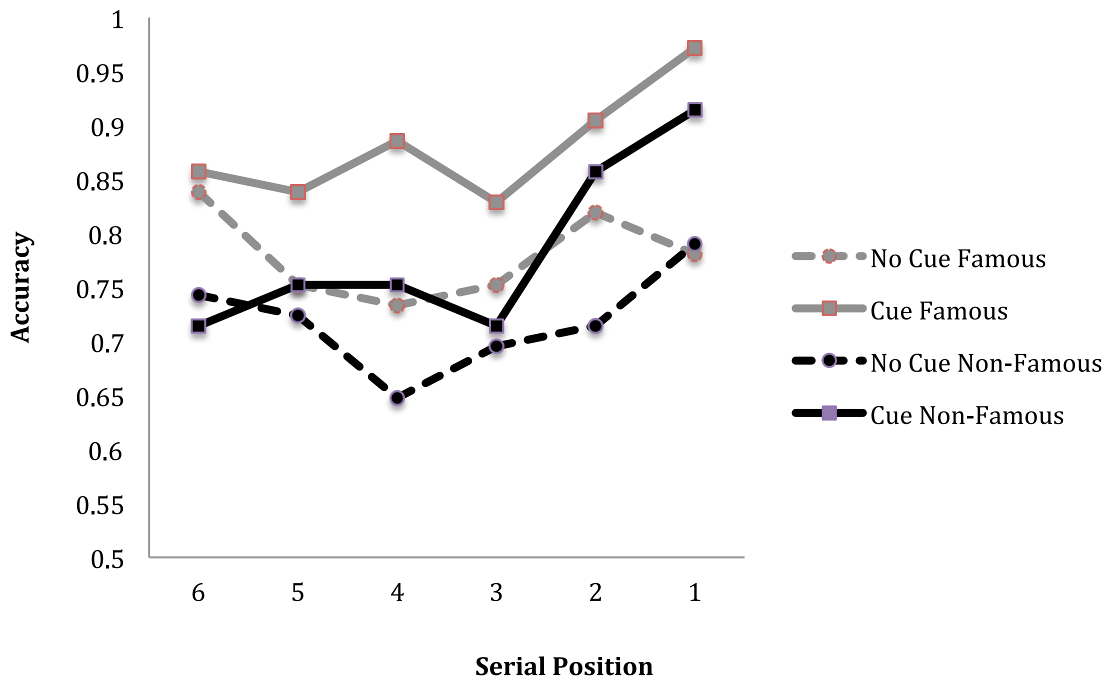

Figure 3. Accuracy (proportion of correct trials) on the change detection task for famous and non-famous faces in the cue and no-cue conditions at each serial position.

Discussion

Given that most people will likely have seen the famous faces countless times, these representations should be well established in LTM. The familiarity and complex nature of faces should make it easier to encode the stimuli and hold them in STM (Jackson & Raymond, 2008). As predicted, participants were more likely to detect changes for famous faces supporting the hypothesis for the familiarity effect. They were also more likely to make an accurate decision in the post-cue condition, although these variables did not interact. This is in line with past research stating that post-cue effects are more likely to be found with meaningful stimuli (Beck & van Lamsweerde, 2010; Hollingworth, 2003). There was not significant evidence of the cue being especially helpful in longer lags, but could still aid the decision process across all lags. The interaction between serial position and post-cue in the first analysis shows that at least one lag in the cue condition had significantly higher accuracy. It was found that lag 1 was significantly higher than lags 3, 4, 5, and 6. Most likely because it was the most easily accessed in memory and the cue directed attention right to it. Unfortunately, the 3-way interaction was not found between the variables. Without this interaction, the issue of aLTM bringing information into STM is still up for debate, as well as the issue regarding if memories disappear from sudden death, or because of interference.

One of the greatest limitations with this study was the lack of power. Hopefully with more participants, the hypothesized results would be found, specifically, the interaction between type of memory and the post-cue. There could also have been issues with the methodology. Because of time and money restraints, the nonfamous faces were combined from two databases. This could have led to higher accuracy by switches between the databases being more noticeable. With a validated set of faces the results could be more accurate.

With more time for analysis it would be interesting to examine the gaze durations from the task. Hollingworth and Henderson (2002) found a relationship between length of gaze duration and the likelihood of detecting a change. Reports from the eye-tracking program would need to be investigated. Another interesting area to investigate with faces is the attractive aspect. It is feasible to suggest that the attractiveness of the famous faces led them to be looked at longer than the nonfamous people. Therefore, these faces would be more likely to be encoded and retrieved for a more accurate comparison. Having the faces rated on their attractiveness and then examining the gaze durations for the attractive and less attractive faces could examine this.

It is possible that participant fatigue was taking place and towards the end of the experiment, participants were not taking the time to properly encode the faces. Another possibility is that through many trials the participants lose the ability to distinguish between the items on the present test image and those seen on past trials (Winkler, Schroger, & Cowan, 2001). This loss of distinctiveness could present confusion and confound the results. For future research, this experiment could be replicated but with four conditions: famous with post-cue, famous with no cue, nonfamous with post-cue, and nonfamous with no cue. This would lead to fewer trials, less participant fatigue, and hopefully a 3-way interaction.

While we did not find significant evidence of a post-cue combined with familiarity of famous faces aiding activation of LTM representations, we did find three separate main effects. The familiarity effect found agrees with past research by Jackson and Raymond (2008). Beck and van Lamsweerde (2010) and Hollingworth (2003) both found evidence of a post-cue effect. Also the effect of serial position is easily explained by the face being in FOA will be the easiest to compare to representations in STM. This is in line with past research of FOA (Oberauer, 2002; McElree, 2006; Nee & Jonides, 2013). However, we did not find evidence of to determine if this was due to a 2-state or 3-state memory. While these main effects support past results, an interaction between these effects would provide evidence of aLTM aiding STM in a 3-state model. Future research with more power and possibly improved methodology could provide answers.

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