Published in final edited form as:
Memory. 2012 January ; 20(1): 48–62. doi:10.1080/09658211.2011.633919.

Distinguishing highly confident accurate and inaccurate memory: insights about relevant and irrelevant influences on memory confidence

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Abstract

It is generally believed that accuracy and confidence in one's memory are related, but there are many instances when they diverge. Accordingly, it is important to disentangle the factors which contribute to memory accuracy and confidence, especially those factors that contribute to confidence, but not accuracy. We used eye movements to separately measure fluent cue processing, the target recognition experience, and relative evidence assessment on recognition confidence and accuracy. Eye movements were monitored during a face-scene associative recognition task, in which participants first saw a scene cue, followed by a forced-choice recognition test for the associated face, with confidence ratings. Eye movement indices of the target recognition experience were largely indicative of accuracy, and showed a relationship to confidence for accurate decisions. In contrast, eye movements during the scene cue raised the possibility that more fluent cue processing was related to higher confidence for both accurate and inaccurate recognition decisions. In a second experiment, we manipulated cue familiarity, and therefore cue fluency. Participants showed higher confidence for cue-target associations for when the cue was more familiar, especially for incorrect responses. These results suggest that over-reliance on cue familiarity and under-reliance on the target recognition experience may lead to erroneous confidence.

Introduction

Confidence in a memory is seen as a good indicator of the accuracy of a memory by lay people (Wells, Olson, & Charman, 2002) and researchers alike (Stretch & Wixted, 1998; Yonelinas, 1994), yet there are striking cases in which confidence and accuracy diverge and people can confidently and vividly remember incorrect information (e.g., Loftus & Pickrell, 1995; Norman & Schacter, 1997; Roediger & McDermott, 1995; Schacter & Dodson, 2001). Thus, memory confidence and accuracy are best considered as two different variables, each of which is based on numerous factors, some of which may be the same, and some of which may be different (Wells, et al., 2002). Understanding the factors that influence confidence, especially ones that do not influence accuracy, is critical for both distinguishing highly confident accurate and highly confident inaccurate memory, and for determining when confidence and accuracy have a strong relationship. Accordingly, the goal of our studies is to identify which factors lead to confidence judgments that are congruent with accuracy, and those that are incongruent with accuracy. In other words, we're interested in what leads to

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high confidence in accurate recognition or low confidence in inaccurate recognition, and what leads to high confidence in inaccurate recognition or low confidence in accurate recognition. We will refer to factors that lead to congruent confidence-accuracy judgments as *relevant factors* because they are relevant for making confidence judgments that are congruent with recognition accuracy. Similarly, factors that lead to incongruent confidence-accuracy judgments will be referred to as *irrelevant factors* because they are not relevant for making confidence judgments that are congruent with recognition accuracy.

The majority of research on the basis of confidence judgments has focused on what will be referred to as the *target recognition experience* (Chua, Schacter, Rand-Giovannetti, & Sperling, 2006; Chua, Schacter, & Sperling, 2009a, 2009b; Dodson, Bawa, & Krueger, 2007; C. M. Kelley & Lindsay, 1993; Koriat & Goldsmith, 1996; Nelson & Narens, 1990; Robinson, Johnson, & Herndon, 1997). In such cases, confidence judgments are thought to be based on the online experience of remembering information about a previously studied *target*. The accuracy of confidence judgments based on the target recognition experience is often similar to memory accuracy, which is why many believe that confidence is a good indicator of accuracy (Wells, et al., 2002; Yonelinas, 1994); accordingly, the target recognition experience is considered a relevant source of information for confidence. Previous research has shown that confidence judgments can be influenced by several specific aspects of the target recognition experience, including target familiarity (Yonelinas, 1994), vividness of recollected details (Robinson, Johnson, & Robertson, 2000), and how quickly or easily the target information is retrieved (C. M. Kelley & Lindsay, 1993; Robinson, et al., 1997). In other words, memories that are retrieved more quickly and easily are often associated with higher confidence than memories that are more effortful to retrieve, and these factors tend to be associated with accuracy. Thus, it is not surprising that confidence judgments that rely on the target recognition experience are often accompanied by accurate recognition responses (Brewer, Keast, & Rishworth, 2002; Robinson, et al., 2000; Sporer, Penrod, Read, & Cutler, 1995), and we expect that this will be a relevant factor that influences confidence in that it leads to congruency in recognition confidence and accuracy.

However, given that confidence and accuracy can diverge (Busey, Tunnicliff, Loftus, & Loftus, 2000; Perfect, Hollins, & Hunt, 2000; Petrusic & Baranski, 2003; Robinson, et al., 2000; Shaw & Zerr, 2003; Wells, Olson, & Charman, 2003), it is clear that irrelevant and less diagnostic factors must also influence confidence. Memory confidence decisions are often elicited in the context of cued recall or recognition paradigms, in which a participant is presented with an item to cue their memory for the associated target, and then confidence judgments are given after the participant has retrieved, or attempted to retrieve, the target information (Brewer, et al., 2002; Busey, et al., 2000; Robinson, et al., 2000). Therefore, we investigated how factors related to processing of the cue are influencing confidence. Based on prior reports that retrieval fluency can influence metacognitive judgments (Benjamin, Bjork, & Schwartz, 1998), and many reports of fluency being misattributed for familiarity (Jacoby, Allan, Collins, & Larwill, 1988; Jacoby, Kelley, Brown, & Jasechko, 1989; Johnson, Hashtroudi, & Lindsay, 1993; C. M. Kelley & Jacoby, 1996; C. M. Kelley & Lindsay, 1993; Mather, Shafir, & Johnson, 2000) we investigated the effects of fluent cue processing on confidence for retrieving the associated target using eye movement measures in Experiment 1 and a repetition manipulation in Experiment 2.

Another factor that could influence confidence is *relative evidence* for one alternative compared to the other alternatives in a given test (Koriat, Lichtenstein, & Fischhoff, 1980; McKenzie, 1997). Whereas the target recognition experience is based on memory for a single item or alternative, assessing relative evidence involves a deliberate, reasoned process that considers and compares multiple alternatives, and is thus more analytic in nature

(Koriat, 2000; Koriat, Nussinson, Bless, & Shaked, 2008). A strategy such as the “process of elimination” is an example of using relative evidence. In such a case, people may have higher confidence in a weak memory when there is even weaker or contradictory evidence for the other alternatives. The influence of relative evidence on recognition confidence has been most extensively studied by comparing simultaneous and sequential lineups using eyewitness paradigms (Lindsay & Wells, 1985; Sporer, 1993; Wells & Olson, 2003). In forced choice tasks, like the simultaneous lineup, participants may make relative judgments about the similarity of the alternatives to his or her memory of the target stimulus (Lindsay & Wells, 1985; Sporer, 1993). If the alternatives, or evidence for the alternatives, are very similar to one another, then participants may experience increased conflict and choice difficulty, which may lead to lower confidence (Fleck, Daselaar, Dobbins, & Cabeza, 2006; Peterson & Pitz, 1988; Zakay, 1985). Thus, in Experiment 1, we examined how relative evidence influences confidence, and predicted that increased conflict, indexed indirectly via eye movement behavior, will lead to lower memory confidence regardless of accuracy.

The goal of Experiment 1 was to examine how confidence judgments are influenced by cue processing fluency, the target recognition experience, and relative evidence assessment. Although previous studies have investigated this issue by manipulating one factor and examining how that manipulation influenced confidence judgments (e.g., Brewer, et al., 2002; Koriat, et al., 2008), no study, to our knowledge, has evaluated all three factors in the same paradigm. We therefore used eye movements to indirectly evaluate each of these factors in the same study. Using an indirect method such as eye movement monitoring is critical for disentangling these factors because asking participants to make explicit judgments about the cue may influence subsequent confidence in a desire to be consistent. Accordingly, we used a paradigm in which participants learned face-scene pairs, and then performed a cued, forced choice recognition task while their eye movements were recorded (D. E. Hannula & Ranganath, 2009; D. E. Hannula, Ryan, Tranel, & Cohen, 2007). Each test trial commenced with the presentation of a scene cue, followed by 3 faces superimposed on the scene. Participants decided which of the 3 faces was previously studied with that scene, and then indicated their confidence in their decision. As described below, this paradigm allowed us to separately measure whether cue processing fluency, the target recognition experience, and assessment of relative evidence influence confidence and accuracy because the retrieval cue (i.e., the scene) and the target recognition decision (i.e., 3-face display) are separated in time; thus, we could examine whether and how eye movement measures that index memory for the cue and the associated target were related to memory confidence and accuracy.

To investigate whether cue processing fluency influences confidence in episodic recognition of an associated target, we capitalized on the sensitivity of eye movements to index processing fluency of individual items (e.g., scenic images). Previous work has shown that as processing of items becomes increasingly fluent (e.g., through repeated exposure), participants make longer fixations that are directed to fewer features/elements of the picture (e.g., Althoff & Cohen, 1999; Ryan, et al., 2000). To the extent that cue processing fluency influences target recognition confidence, we predict that there will be fewer fixations during the scene cue for trials in which participants showed higher confidence in their target recognition decision.

As mentioned above, the target recognition experience has been shown to influence memory confidence and accuracy, and thus is relevant for confidence-accuracy congruency. To examine the influence of the target recognition experience on confidence and accuracy in the current work we capitalize on an eye-movement-based relational memory that has been documented in the literature. Previous work using a paradigm like the one used here has shown that when the 3-face test display is presented, participants look disproportionately at the face that was paired with the scene during the study phase. This eye-movement-based relational memory effect was significant just 500-750 msec after display onset, and preceded the explicit recognition response by as much as 500-1000 ms (Hannula, et al., 2007). Based on these results, it was suggested that eye movements are drawn automatically and obligatorily to the associate when a scene cue has been presented, and that disproportionate viewing of the associate may precede and help give rise to conscious awareness of the match (see Hannula, et al., 2010). This eye-movement-based *relational* memory effect is qualitatively different from the *item-based effect* mentioned previously. While both effects reflect memory for previously studied information, they have different signatures and index different types of memory.

If the target recognition experience has similar influences on confidence and accuracy, then participants should spend more time viewing correctly identified associates, particularly those endorsed with high confidence, than faces selected in error on incorrect trials. High confidence correct trials might also elicit earlier viewing of the associate than incorrect trials or trials associated with lower levels of confidence. To examine the target recognition experience, we used two eye movement measures: 1) the proportion of time spent viewing the correctly chosen face for accurate memory trials, or the incorrectly chosen face for inaccurate memory trials, across different confidence levels during the 3-alternative forced choice face recognition task, and 2) how quickly after stimulus onset disproportionate viewing of the chosen face emerged across different levels of confidence and accuracy.

Finally, eye movements can also be used to examine the assessment of relative evidence among alternatives. To measure relative evidence assessment, we examined how many transitions (i.e., saccades from one face to another) were made while the 3-face display was in view (Pochon, Riis, Sanfey, Nystrom, & Cohen, 2008; Reutskaja, Nagel, Camerer, & Rangel, 2011). Previous work, in which participants were required to decide which person (from two alternatives) was more attractive, has shown that when the faces are similarly attractive, there are more transitions from one face to the other compared to when the faces differ in attractiveness (Pochon, et al., 2008). However, this occurred only when participants had a long enough decision time (i.e., for trials that were 5.6 s or 7.2 s but not 3.6 s). This suggests that in a non-memory paradigm, transitions may be sensitive to decision conflict and that these judgments with longer decision times may be based on assessing relative evidence. In the current investigation, we expect that looking among, or transitions between faces in the test display reflect a comparison among the faces and a relative assessment of evidence among options. Therefore, we predicted there would be more transitions among the faces when participants have less confidence in their memories.

In summary, eye movements can be used as an index of memory (for review, see D.E. Hannula, et al., 2010), and thus can be used to determine whether cue processing fluency, target recognition experience, or relative evidence assessment influence recognition confidence. Importantly, with Experiment 1 we examined whether they did so differently for accurate and inaccurate memory, and we examined their joint contribution to the confidence response given. We predicted that eye movements during the cue and target would correlate with confidence for accurate memory because experience-based judgments were more likely to be accurate. In contrast, we expected that for inaccurate memory, eye movements during the cue, but not the target, would correlate with confidence and that overconfidence for inaccurate memory would be related to reliance on non-diagnostic or irrelevant information. In Experiment 2, we followed up our findings on fluent cue processing, and examined whether increased cue familiarity due to repeated exposure would also influence confidence, and predicted that there would be higher confidence, but equivalent associative recognition accuracy, for trials in which the scene was viewed more often during study compared to trials in which the scene was viewed less often.

Experiment 1

Methods

Participants—Data were analyzed from 24 undergraduate students (ages 19-22; 13F/11M) at the University of California, Davis, who were compensated with course credit. Informed consent was given from all participants in a manner approved by the Institutional Review Board at the University of California, Davis. Additional data from other participants were excluded because eye position could not be reliably calibrated, memory performance was at ceiling or floor, or there were too few trials per condition to reliably evaluate the eye movement data.

Behavioral Paradigm—Presentation (http://www.neurobs.com/) software was used to present stimuli and record responses. Participants sat in a stationary, comfortable chair approximately 35 inches from a secondary monitor on which they viewed the stimuli.

Experimental stimuli consisted of 144 color face images (72 F/72 M) and 120 real world scene images that have been used in previous experiments (D. E. Hannula & Ranganath, 2009; D. E. Hannula, et al., 2007). Each face was 280 × 280 pixels on a 300 × 300 pixel gray background (for details, see Althoff & Cohen, 1999) and scenes were 800 × 600 pixels. Nine additional face images and three additional scene images were used for instructions and practice of the behavioral paradigm.

The experimental paradigm consisted of three face-scene relational encoding blocks and three face-scene recognition test blocks with confidence ratings, and were presented such that a single study block was followed immediately by the corresponding test block (Figure 1), which was modeled after previous work (D. E. Hannula & Ranganath, 2009). During study blocks, each trial began by presenting the scene image on the screen for 3 seconds, which was then followed by a fixation cross, and then a face appeared that was superimposed on the center of the scene for 5 seconds. Participants were instructed to indicate by button press how much the person in the picture liked the scene on a scale from 1 to 5 (1=really disliked, 5=really liked) and to try to remember the face-scene pair for later testing. There were a total of 108 study trials, with 36 trials in each study block. During test blocks, eye position was monitored. Test trials began with the presentation of a scene for 3 seconds (*scene cue*), which was followed by a central fixation cross. Once the participant was looking at the fixation cross, the experimenter advanced the trial. This was done to ensure that eye position began in the same place before each 3-face display was presented. The 3-face display consisted of 3 faces superimposed on the scene that had just been presented, and remained in view for 10 seconds. During this time, participants had to indicate which face (left, right, or bottom) was originally studied with that scene, in a 3 alternative forced choice recognition task (3AFC). One of the faces had been paired with the scene, and 2 had been previously studied with other scenes. Thus each face was familiar, and the relational recognition task could not be solved on the basis of face familiarity alone. The correct face occurred equally in the left, right, or bottom position across the experiment. Face stimuli were only used once during recognition, and there were 36 of these trials total, with 12 in each block. There were 12 additional trials consisting of novel scenes and novel faces, with 4 in each block. Participants were instructed to go ahead and choose a face even if they did not remember having seen them before. The recognition trials were then followed by confidence ratings, and participants indicated how sure they were that they chose the correct face on a 1-5 scale. Participants were instructed to choose “1” if they were guessing, “2” if they were 25% sure, “3” if they were 50% sure, “4” if they were 75% sure, and “5” if they were 100% sure. Although the novel trials were included in the paradigm, almost all of them were given a low confidence rating, and thus were not analyzed. “(Figure 1 about here)”.

Eye-tracking Acquisition & Analyses—Eye movements were recorded using an Applied Sciences Laboratories (ASL, Inc. Bedford, MA) Model R6 remote eye tracking system at a rate of 60Hz. Only trials in which eye position was reliably maintained were included in analyses. For the *Scene Cue*, trials were eliminated if total viewing time was less than 2000 msec or was more than two standard deviations below the participant's mean *scene cue* viewing time. For the *3-face display*, trials were eliminated if total viewing time was less than 6666 msec or was more than two standard deviations below the participant's mean *3-face display* viewing time. Although previous studies have examined eye movements in single trials (Smith & Squire, 2008)(Exp. 2, Block 3), we required a minimum of 3 usable trials in each condition for a participant's data to be included in the analyses. On average, eye position was reliably maintained for both the scene cue and 3-face test display on 32.67 ± 0.70 of the 36 previously seen face-scene pairs (average of 18.54 ± 0.76 hits, 14.38 ± 0.74 misses). The average number of trials for the different response types broken down by confidence and accuracy are presented in Table 1. Because of low trial numbers, confidence ratings were categorized as high (4 or 5 on the response scale), medium (3 on the response scale), and low (1 or 2 on the response scale). Thus, there were 6 response types of interest: High Confidence Hits, Medium Confidence Hits, Low Confidence Hits, High Confidence Misses, Medium Confidence Misses, and Low Confidence Misses. "(Insert Table 1 About Here)".

Several different eye-movement measures, described below, were used to examine separately the relationship between eye movements, accuracy, and confidence ratings for the scene cue and the 3-face test display to test the influence of cue-related processing, the target recognition experience, and relative evidence assessment on recognition confidence.

Cue Processing Fluency: The number of fixations made during each scene cue was calculated for every trial, and were compared across trials based on subsequent face-scene recognition accuracy and memory confidence using repeated measures ANOVAs. Fixations were calculated offline using ASL's software package, EYENAL, with the constraint that subsequent samples were averaged together into a single fixation if changes in gaze point across samples were less than 1 degree of visual angle, and when combined, had a minimum duration of at least 100 msec.

Target recognition experience: For the 3-face display we took a region of interest (ROI) approach, and there were 4 ROIs for each trial: the background scene, and each of the 3 faces. Within each trial, one face ROI was our primary ROI. For hits, we were primarily interested in viewing directed toward the correctly chosen face (i.e. the face that had been associated with the scene during the study trials), whereas for misses, we were primarily interested in viewing directed toward the incorrectly chosen face. Differences in viewing between these ROIs were considered memory-related because they occurred above and beyond viewing related to choice behavior, which was equated (i.e., the face was selected in both cases).

Using these primary ROIs, we then compared viewing behavior between the 6 trial types that were defined based on memory confidence and recognition accuracy as outlined above. Eye movement behavior related to the target recognition experience was evaluated using two different measures, each described in turn below.

1. The *proportion of total viewing time* directed toward the primary face ROI (i.e., the correctly chosen face for hits and the incorrectly chosen face for misses) collapsed across the first 5 seconds of the trial was calculated for each trial. We focused on the first 5 seconds because we were primarily interested in eye movement effects that occurred before the participants' responses. However, we also conducted

analyses collapsed across the entire 10 second trial, and these showed similar results to the analyses of the first 5 seconds.

2. *Time to Disproportionate Viewing* was calculated to examine whether eye movement based memory effects emerged earlier in time following 3-face display onset based on the level of confidence expressed (i.e., whether speed of retrieval influenced confidence). Time-courses of viewing were generated by examining the proportion of total viewing time directed towards the primary face ROI in successive 500 msec time bins over the course of the trial beginning with stimulus onset. Our criteria for disproportionate viewing was that viewing of the chosen face had to exceed viewing of the other two non-chosen faces within a given 3-face display by at least 5% over two consecutive 500 msec time bins on a trial-by-trial basis. For analysis purposes, the time was recorded as the mid-point of the two time bins (i.e., if the two time bins were 500-1000 msec and 1000-1500 msec, the time was recorded as 1000 msec). On the rare instance that a trial did not meet our criteria for disproportionate viewing (mean: 0.875 ± 0.29 trials per subject), the time to disproportionate viewing was entered as 10,000 msec (the maximum trial length). The rationale for including, rather than excluding these trials, is that it may be informative that participants are not showing evidence of disproportionate viewing during specific trials. Because this could skew the time to disproportionate viewing, the median, rather than the mean, time to disproportionate viewing for each subject for each condition was entered in a repeated measures ANOVA to examine whether memories accompanied by higher confidence exhibited earlier disproportionate viewing. Analyses that used the mean time to disproportionate viewing and analyses that excluded trials that did not meet criteria for disproportionate viewing were also conducted, and showed similar results to the reported analyses.

Relative evidence assessment: The total number of *transitions* (or movement of the eyes) from one ROI to another within a given display, was used to examine relative assessment of the different options. Using the same logic as eye tracking paradigms of decision making, in which there are more transitions when choices are more similar in value and decisions are more difficult, we expected that more transitions among the faces reflected greater choice difficulty and an assessment of relative evidence (Pochon, et al., 2008; Reutskaja, et al., 2011). Choice difficulty was expected to be reflected in measures of memory confidence and accuracy, and increased choice difficulty was expected to manifest in viewing behavior as more transitions among ROIs within a display.

Statistical Analyses—The relationships between memory confidence, accuracy, and viewing behavior were examined using omnibus repeated measures ANOVAs and subsequent post-hoc comparisons. The primary factors tested were confidence (high, medium, and low) and accuracy (hits and misses). Mauchly's test of sphericity was used to ensure that the assumption of sphericity was met. If the assumption was violated, the Greenhouse-Geisser correction was applied, and the epsilon (ε) is reported. Follow-up analyses consisted of two-tailed paired t-tests.

Results and Discussion

Task Performance—Participants performed well on the recognition task, correctly identifying the face that was previously paired with the scene 56 ± 2 % of the time, and each subject performed above the chance rate of 33%. Participants gave a higher confidence rating using the 1-5 scale for hits compared to misses, $t(23)=11.476$, $p<0.001$ (hits: 3.61 ± 0.09; misses: 2.71 ± 0.08). Accuracy was greater for higher confidence levels (high:73.0 ± 2.6 %; medium: 48.6 ± 3%; low: 38.1 ± 2.5%).

Reaction times for associative recognition responses are presented in Table 1. A factorial analysis of the effects of accuracy (hits, misses) and confidence level (high, medium, low) revealed a main effect of confidence, $F(2,46)=7.576$, $p<0.005$, and a significant confidence × accuracy interaction, $F(2,46)=3.243$, $p<0.05$, but no significant main effect of accuracy, $F(1,23)=0.336$, $p>0.5$. Follow-up analyses showed that High Confidence Hits were faster than Medium Confidence Hits, $t(23)=4.334$, $p<0.001$, and Low Confidence Hits, $t(23)=3.681$, $p<0.001$. There were no significant differences between High Confidence Misses, Medium Confidence Misses, and Low Confidence Misses, $F(1,23)=1.094$, $p=0.334$, and no significant differences, all t's <1.5, all p's>0.10, between hits and misses within any confidence level.

Eye-Movement Behavior

Cue Processing Fluency Influences Confidence Judgments for Accurate and Inaccurate Recognition: We predicted that cue processing fluency would influence confidence judgments, but that it would be less diagnostic of accuracy, and would influence confidence for both accurate and inaccurate memory. We reasoned that cognitive processes associated with the retrieval cue (i.e., the scene) should influence the number of fixations made during viewing of the scene cue based on prior work documenting that eye movements can index processing fluency (Althoff & Cohen, 1999; Ryan, Althoff, Whitlow, & Cohen, 2000; Sharot, Davidson, Carson, & Phelps, 2008; Smith, Hopkins, & Squire, 2006; Smith & Squire, 2008). An ANOVA with accuracy (hits, misses) and confidence level (high, medium, low) as factors revealed a main effect of confidence, $F(2,46)=4.886$, $p<0.05$, $\varepsilon=0.9213$, on the number of fixations made during the scene cue, and no other significant main effects or interactions, all F's < 2, all p's > 0.2 (Figure 2). There were fewer fixations to the scene cue on trials in which participants had high confidence in their subsequent recognition of the associated face compared to subsequent medium confidence decisions for both hits, $t(23)=2.072$, $p<0.05$ (High: 7.34 ± 0.30; Medium: 7.65 ± 0.30) and misses, $t(23)=2.844$, $p<0.01$ (High: 6.77 ± 0.34; Medium: 7.45 ± 0.32). High Confidence Misses also showed fewer fixations than Low Confidence Misses, $t(23)=2.412$, $p<0.05$ (Low: 7.321 ± 0.35). None of the other within factor t-tests were significant, all t's<2, all p's > 0.5. "(Insert Figure 2 about here)".

We next performed analyses to rule out potentially confounding factors. For example, differences in the number of fixations directed to scene cues could be driven by chance variability in the amount of total time spent viewing the cues. A direct analysis, however, revealed no significant differences in the total amount of viewing data available among conditions, all F's<1.33, p's>0.24. Another possible explanation for differences in the number of fixations as a function of confidence is that they could have been driven by item effects if certain scenes were more likely to lead to a specific recognition response. Examination of average memory performance for each scene cue, however, revealed that recognition responses were randomly distributed for the overwhelming majority of items and that only 1 of the 120 scene cues consistently elicited one particular response type (i.e., medium confidence miss). Thus, the results indicate that fewer fixations during the scene cue were systematically related to subsequent high confidence in recognition, for both accurate and inaccurate trials.

Greater and Earlier Viewing of the Correct Face with Increasing Confidence for Accurate Memory: We hypothesized that the target recognition experience exerts similar influences on confidence and accuracy. Our first analyses investigated the relationship between confidence, accuracy, and proportion of viewing time directed towards the chosen face. If the target recognition experience exerts a similar influence on confidence and accuracy, we would expect participants to spend more time viewing correctly identified faces compared to the chosen faces on incorrect trials, and we would expect viewing of correctly identified faces to increase with increasing confidence. Results from a 2 × 3 repeated measures ANOVA with accuracy (hits, misses) and confidence level (high, medium, low) as factors were consistent with these predictions and showed a significant confidence × accuracy interaction, $F(2,46)=6.128$, $p<0.005$, as well as main effects of both confidence, $F(2,46)=3.286$, $p<0.05$, and accuracy, $F(1,23)=7.164$, $p<0.05$. Consistent with our prediction, there was greater viewing of the chosen face for hits compared to misses for high, $t(23)=3.406$, $p<0.005$, and medium confidence responses, $t(23)=2.068$, $p<0.05$, but not low confidence responses, $t(23)=1.03$, $p=0.17$ (Figure 3). Consistent with our second prediction, there was a significant effect of confidence on proportion of viewing time, $F(2,46)=15.143$, $p<0.0001$, such that the time spent viewing a correctly chosen face increased with increasing confidence (greater viewing for high confidence hits compared to medium confidence hits, $t(23)=3.141$, $p<0.005$; greater viewing for medium confidence hits compared to low confidence hits, $t(23)=2.529$, $p<0.05$; linear effect, $F(1,23)=27.426$, $p<0.0001$). In contrast, confidence was not significantly associated with viewing behavior on miss trials, $F(2,46)=0.414$, $p=0.664$ (Figure 3). “(Insert Figure 3 about here)”.

We also predicted that the speed or ease of retrieval should be a significant contributor to confidence in recognition memory. To test this prediction, we conducted detailed analyses of the time course of disproportionate viewing of the chosen face (i.e., the earliest time that participants’ viewed that face at least 5% more than the other two non-chosen faces for two consecutive 500 msec time bins). Consistent with the idea that people are more confident when information is retrieved more quickly or easily, there was earlier disproportionate viewing of the correctly chosen face with increasing confidence for accurate memory (Figure 4; linear effect of confidence for correct, $F(1,23)=12.872$, $p<0.002$); there was no effect of confidence on the time course of disproportionate viewing for inaccurate memory, $F(1,23)=1.114$, $p=0.302$. “(Insert Figure 4 about here)”.

Transitions among alternatives mainly relates to accuracy rather than confidence: Our final analyses focused on the role of relative evidence assessment in confidence judgments (Koriat, et al., 1980; McKenzie, 1997). We used the number of transitions among the three faces as a means of operationalizing relative evidence assessment based on the premise that the number of transitions should increase with increasing similarity in evidence among the alternatives (Pochon, et al., 2008; Reutskaja, et al., 2011). If relative evidence contributes to confidence judgments, we would therefore predict that, on both accurate and inaccurate trials, there would be fewer transitions for high confidence responses and more transitions for lower confidence responses. An analysis of these data, however, revealed no significant main effect of confidence, $F(2,46)=2.01$, $p=0.146$, although a significant effect of accuracy was observed, $F(1,23)=4.821$, $p<0.05$, and this was qualified by a marginal confidence × accuracy interaction, $F(2,46)=3.103$, $p=0.054$. Follow-up analyses revealed fewer transitions for hits compared to misses for High (Hits: 9.82 ± 0.39; Misses: 10.36 ± 0.43; $t(23) = 2.186$, $p<0.05$) and Medium Confidence decisions (Hits: 9.46 ± 0.49; Misses: 10.28 ± 0.47; $t(23) = 1.986$, $p=0.056$), but not for Low Confidence decisions (Hits: 10.75 ± 0.44; Misses: 10.36 ± 0.43, $t(23)=1.081$, $p=0.291$). Counter to our hypothesis, overall these data suggest that in a forced choice task, less distributed viewing among the choices is indicative of accuracy. Low Confidence Hits, which likely reflect guessing and weak evidence for each of the alternatives, appear to be an exception.

Experiment 2

The results from the previous study suggested that fluent processing of a retrieval cue contributes to confidence for the associated target, and that over-reliance on cue processing fluency may lead to inflated confidence in erroneous target identification. Previous work has shown that increased fluency can lead to increased feelings of familiarity (C. Kelley & Jacoby, 1990, 1998), suggesting that cue familiarity may also lead to inflated confidence. This is supported by previous work in the metacognitive literature using general knowledge paradigms; familiarity with the general topic leads to inflated confidence in the answers (Koriat, et al., 2008). Although it is reasonable to propose that participants' feelings of familiarity with the cue led to greater confidence in recognition of targets, we cannot be certain because we could not directly assess participants' familiarity with cues in Experiment 1 (we did not have participants explicitly rate their familiarity with the cue because this metacognitive decision might contaminate their confidence judgments for the face-scene pair). Accordingly, in Experiment 2, we used a frequency manipulation to explicitly test the hypothesis that increased familiarity with the cue leads to higher confidence, especially in the case of incorrect recognition.

Methods

Participants—Full data were collected and analyzed from 24 undergraduate students (ages 19-29; 12F/12M) at Brooklyn College of the City University of New York, who were compensated with course credit. Informed consent was given from all participants in a manner approved by the Institutional Review Board at the Brooklyn College of the City University of New York.

Behavioral Paradigm—This paradigm was very similar to the eye tracking study in Experiment 1, but added a cue familiarization phase for half of the scenes prior to studying the face-scene pairs. During each cue familiarization block, participants viewed 8 scenes for 3 sec, and saw each of these 3 times. They were instructed to view the scene, and did not have an active task. Half of the subjects were familiarized with one set of scenes and the other half were familiarized with the remaining set of scenes. Next, during each study block, participants studied 48 face-scene pairs in a manner similar to the eye tracking study. Then, during each test block, participants were tested with 20 3-face displays in a manner similar to the eye tracking study. Critically though, 8 displays now contained a scene cue that was more familiar (studied a total of 4 times), 8 displays contained a scene cue that was less familiar (studied only once), and 4 displays were novel and contained faces and scenes had not been seen previously. Participants completed 5 familiarization-study-test cycles, and completed 40 test trials with more familiar cues, 40 test trials with less familiar cues, and 20 test trials with novel faces and scenes.

Results and Discussion

Overall, participants performed well on the recognition task, correctly identifying the face that was previously paired with the scene 49.44 ± 2.5 % of the time, and each subject performed above the chance rate of 33%. When comparing trials in which participants were more or less familiar with the scene cue, correct identification rates did not differ significantly (more familiar: 50.21 ± 2.8 %; less familiar: 48.33 ± 2.7 %; $t(23)=0.78$, $p>.4$).

To examine the effect of cue familiarity and accuracy on memory confidence, the mean confidence rating (using the 1-5 scale) was entered in to a 2 × 2 Repeated Measures ANOVA (accuracy × familiarity). There was a significant main effect of accuracy, with higher confidence for correct identifications compared to incorrect identifications [$F(1,23)=31.37$, $p<0.00001$; see Figure 5].Follow up paired t-tests showed that participants were more confident in their correct identifications than their incorrect identifications regardless of whether the scene was more familiar (hits: 3.12 ± 0.13; misses: 2.49 ± 0.14; $t(23)=4.20$, $p<0.0005$) or less familiar (hits: 3.00 ± 0.12; misses: 2.26 ± 0.11; $t(23)=6.14$, $p<0.00001$). "(Insert Figure 5 About Here)"

As predicted by the previous eye tracking study, there was also a significant main effect of cue familiarity on confidence; increased familiarity with the scene cue resulted in higher confidence responses [$F(1,23)=6.84$, $p<0.02$; see Figure 5]. In other words, confidence ratings were higher for identifications when the scenes were more familiar compared to when they were less familiar. Subsequent paired t-tests revealed that this was mainly driven by higher confidence when the scenes were more familiar and the response was incorrect [$t(23)=3.73$, $p<0.0011$; see Figure 5]. Although the confidence ratings for correct identifications did not significantly differ for more and less familiar cues [$t(23)=1.07$, $p>0.12$], the ANOVA revealed no significant accuracy × cue familiarity interaction [$F(1,23)=0.89$, $p>0.35$]. This suggests that cue familiarity influences confidence, but other factors related to target recognition may trump this effect for correct identifications. The reported results also suggest that high confidence errors could result from misattributing cue familiarity for familiarity of the cue-target pair. “(Insert Figure 5 about here)”.

General Discussion

Identification of the factors that distinguish highly confident accurate memory from highly confident inaccurate memory, and understanding what leads an individual to be highly confident in an inaccurate memory are important issues in the study of memory and metamemory (e.g., Nelson & Narens, 1990), and also in applied settings (e.g., Wells, et al., 2002). In Experiment 1, we used eye movements to measure cue processing fluency, the target recognition experience, and relative evidence assessment. We found that the target recognition experience was directly related to confidence and accuracy, whereas eye movement indices of more fluent cue processing were related to confidence for both correct and incorrect recognition. In Experiment 2, we tested the hypothesis that increased cue familiarity, which is often accompanied by increased fluency (C. Kelley & Jacoby, 1990, 1998; Whittlesea, 1993), would also lead to enhanced subsequent confidence for the associated target. Confirming our hypothesis, participants gave higher confidence ratings when the cue was more familiar compared to when it was less familiar, and was significant only for incorrect cue-target associations. Taken together, these findings suggest that over-reliance on cue familiarity/fluency without regard to the target recognition experience may lead to erroneous or inflated confidence in target recognition. Furthermore, from an applied perspective, these data suggest that eye movements provide a sensitive measure of memory, and may be useful in distinguishing highly confident accurate and inaccurate memory.

Cue Fluency/Familiarity Influences on Confidence judgments for Episodic Memory—Our findings demonstrated that the fluency of cue-related processing, which we believe to be related to familiarity and memory for the cue, influences subsequent recognition confidence for episodic memory. First, we used eye movements to indirectly assess influences of more fluent cue processing on confidence. This decision was based on numerous findings indicating that participants make fewer fixations and sample fewer different regions of repeated as compared to novel stimuli, which suggests that eye movements provide an index of the a processing advantage, which his often seen for familiar compared to novel items (e.g., Althoff & Cohen, 1999; Ryan, et al., 2000; Smith, et al., 2006; Smith & Squire, 2008). We found that fewer fixations during the cueing period were subsequently associated with higher confidence ratings for both correct and incorrect decisions. To avoid confusion, our results do not support the idea that cue-related processing influences the accuracy of the associative recognition decision, but Experiment 1 presents evidence using eye movements that cue processing fluency is related to the subjective *confidence* in the associative recognition decision. In Experiment 2, we showed that episodic cue familiarity influenced confidence by demonstrating that participants had higher confidence in their erroneous identifications when the scene cue had been seen more frequently, and was therefore more familiar. Putting these two findings together, they suggest that high confidence errors may result from a misattributing the feeling of familiarity with the cue, and the more fluent processing that stronger memory representation affords, for memory of the associated target.

These feelings of cue familiarity, as shown in Experiments 1 & 2, may arise from increased perceptual fluency of the stimulus, and/or through repeated exposure that leads to a stronger representation in memory (Whittlesea, 1993). Although repetition is one way that familiarity of an item can be increased, there is a large body of work showing familiarity does not rely on a repetition manipulation, or a stronger memory representation per se, but may be mediated by conceptual and/or perceptual fluency of the stimulus (e.g., Verfaellie & Cermak, 1999; Wagner & Gabrieli, 1998; Wagner, Stebbins, Masciari, Fleishman, & Gabrieli, 1998; Whittlesea, 1993), as such subjective familiarity can differ for items that have been presented just once during a study phase (e.g., Yonelinas et al. 2005). Therefore, we reason that in Experiment 1, those items to which participants made fewer fixations and were processed more fluently, may have been accompanied by more feelings of familiarity. This is similar to other paradigms that compared eye movements during the presentation of novel stimuli to stimuli that participant's had prior exposure, and showed fewer fixations to the more familiar (Althoff & Cohen, 1999; Ryan, et al., 2000).

There is a large body of work showing that a fluent memory from a past event can influence a subjective judgment on a current situation or lead to memory distortions because of misattribution errors (Jacoby, et al., 1988; Jacoby, et al., 1989; Johnson, et al., 1993; C. M. Kelley & Jacoby, 1996; C. M. Kelley & Lindsay, 1993; Mather, et al., 2000). In one such study, participants were presented with nonfamous names, and then 24 hours later indicated whether or not the same (nonfamous) names referred to famous people (Jacoby, et al., 1989). Results showed that participants misattributed their feelings of familiarity for the name, based on the previous study exposure, as a sign of fame. A key similarity between these paradigms and our own is that participants have not been instructed to pay attention to the source of increased familiarity (i.e., memory for the scene, or source memory for the name). Misattributions may then occur because the source of the familiarity that the subjects experience is non-diagnostic (does not support performance in the case of the associative recognition task) or misleading (in the case of the false fame task). Therefore, it seems likely that during confident incorrect trials participants might have experienced familiarity with the scene cue, and then misattributed that feeling to the strength of the association between the scene and the target face.

Furthermore, several studies in the metacognitive literature have shown that cue familiarity can influence metacognitive judgments, but these have mainly been limited to semantic memory. For example, recent work using general information questions showed that semantic cue familiarity (i.e., familiarity with the overall topic of the general information question) was associated with higher confidence not only for correct answers, but also for incorrect answers (e.g., a person who knew a lot about computers would be more confident on questions about computers(Koriat, 2008). In such paradigms, confidence judgments are based on semantic familiarity with the cue because participants rest on the belief that more knowledge about that topic means they are more accurate, yet this may be an irrelevant factor. Additionally, studies using other metacognitive tasks such as the feeling-of-knowing task (in which participants' predict their ability to recognize a target after failing to recall it), have shown that increased cue familiarity leads to higher feeling-of-knowing judgments in episodic memory paradigms (Koriat & Levy-Sadot, 2001; Metcalfe, Schwartz, & Joaquim, 1993). In one such study, participants learned paired associates, and some of the cue words were paired with multiple associates (Metcalfe, et al., 1993). The cues that were paired with multiple associates were seen more often than cues that were paired with unique associates, and were therefore more familiar. Increased cue familiarity elicited higher feeling-of-knowing ratings without a corresponding increase in accuracy, indicating that the online experience of cue familiarity influences some kinds of prospective metacognitive judgments. Thus, our findings are consistent with the literature and show that confidence in episodic memory, like confidence for semantic memory and feeling-of-knowing judgments, is influenced by cue familiarity.

Target Recognition Experience Influences Confidence and Accuracy—Using eye movement data, we showed that associative recognition decisions and confidence judgments for accurate memory appear to be at least partially based on the target recognition experience. In terms of confidence, there was a linear increase in viewing of targets with greater confidence for accurate memory. We also conducted detailed analyses of the speed of retrieval, which is one aspect of the target recognition experience that may particularly influence confidence (C. M. Kelley & Lindsay, 1993; Robinson, et al., 1997). We found that disproportionate viewing of the correctly identified face emerged faster with higher levels of confidence for accurate memory only. These findings are consistent with previous research showing that the speed of retrieval is one factor that contributes to confidence in memory attributions (C. M. Kelley & Lindsay, 1993; Robinson, et al., 1997). Taken together, these data suggest that confidence and accuracy are related when confidence judgments are based on the target recognition experience.

One goal of this study was to consider cue familiarity and the target recognition experience together. Here, we showed that high confidence in accurate memory was related to both cue familiarity and the target recognition experience. Because the target recognition experience occurred after the cue, it is difficult to know whether the cue influenced these confidence judgments, or whether the target recognition experience superseded any cue effects. This issue remains an open question for further research. In contrast, high confidence for incorrect responses was associated with effects of cue familiarity in the absence of a relationship to the target recognition experience. These findings suggest that high confidence in inaccurate memories may result from the combination of over-reliance on cue information with little to no regard for the target recognition experience.

Little Support for Relative Evidence Assessment from Eye Movements—Based on prior findings indicating that differential weighing of alternatives influences confidence (Koriat, et al., 1980; McKenzie, 1997), we predicted that relative evidence assessment would influence confidence for both accurate and inaccurate memory, and therefore would be less diagnostic of accuracy than the target recognition experience (Koriat, 2000; Koriat, et al., 2008). We proposed that the number of transitions, or looking among, alternatives was a good metric for relative assessment (Pochon, et al., 2008; Reutskaja, et al., 2011). Counter to our predictions, these data suggested that less distibuted viewing among the alternatives is more related to accuracy. One possible explanation for why our predictions were not met is that relative evidence assessment may have made little contribution to confidence in this task (Pochon, Riis, Sanfey, Nystrom, & Cohen, 2008). Alternatively, the number of transitions among alternatives may not have been a good *independent* metric of relative evidence assessment. For example, in high and medium confidence correct trials, participants were directing most of their viewing to the target associate; thus, in these trials, there are also fewer transitions because there is less time to distribute viewing among the alternatives. Future work, likely using a direct measure of relative evidence assessment, is still needed to determine when and if this strategy contributes to confidence judgments and whether it is relevant to accurate retrieval.

Conclusions—The findings presented here indicate that recognition confidence can be influenced by both relevant (target retrieval experience) and irrelevant (cue fluency/ familiarity) factors. Furthermore, the results suggest that eye movements can be used to distinguish highly confident accurate and inaccurate memory, and inform why an individual is erroneously confident. Accordingly, this technique could be useful to assess memory in patients with metacognitive deficits or confabulations.

Acknowledgments

This work was supported by a National Institute on Aging Fellowship F32AG037210 (E.F.C.), a National Institute of Mental Health Fellowship F32MH075513 (D.E.H.), and National Institutes of Health Grant R01MH083734 (C.R.). We also wish to thank Evan Katsuranis for help with software development.

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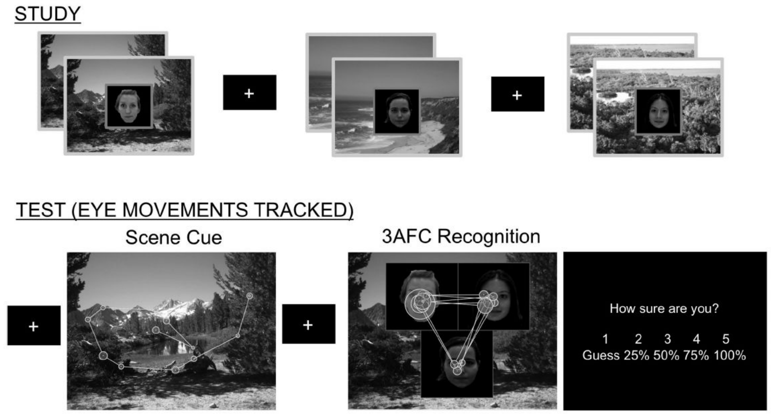

Figure 1.

Example of three study trials and one cued recognition test trial. Eye movements from a single subject are overlaid on the scene cue and 3-face test display. During the 3-face test display, participants performed a 3 alternative forced choice task (3AFC) for which face was previously paired with that scene. Yellow circles represent fixations, with increasing size indicating longer fixations. Green lines represent saccades.

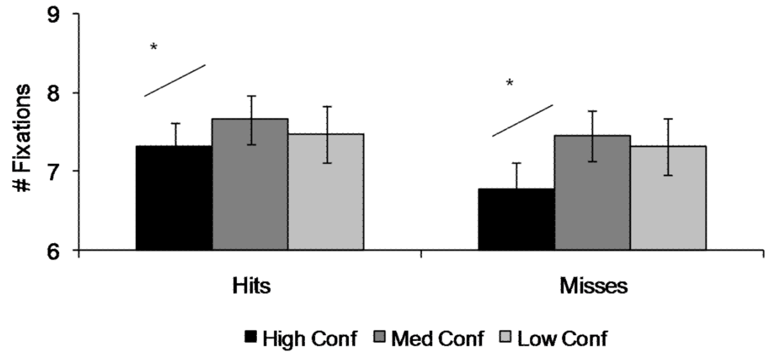

Figure 2.

Number of fixations during the scene cue as a function of confidence. High Confidence trials, regardless of accuracy, were associated with fewer fixations during the cue, indicating fluent processing of the cue influences subsequent target confidence (*$p<0.05$).

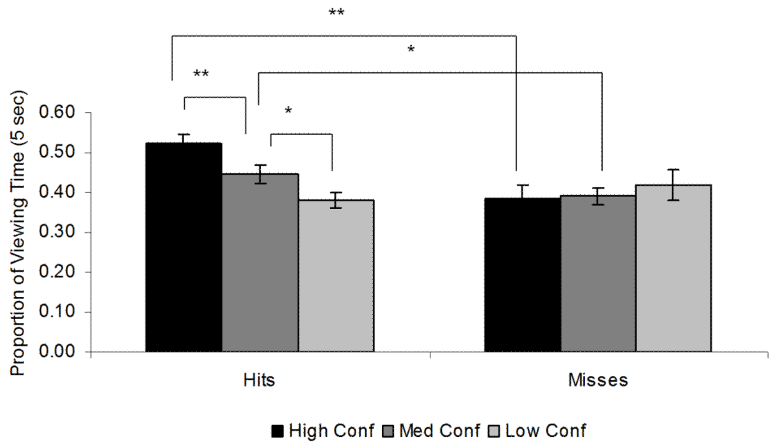

Figure 3.

Viewing behavior related to the target recognition experience was related to memory confidence and accuracy. There was a linear increase in proportion of viewing time with greater confidence for Hits, but not Misses, and for Hits compared to Misses for High and Medium confidence responses (*p<0.05, **p<0.01)gg.

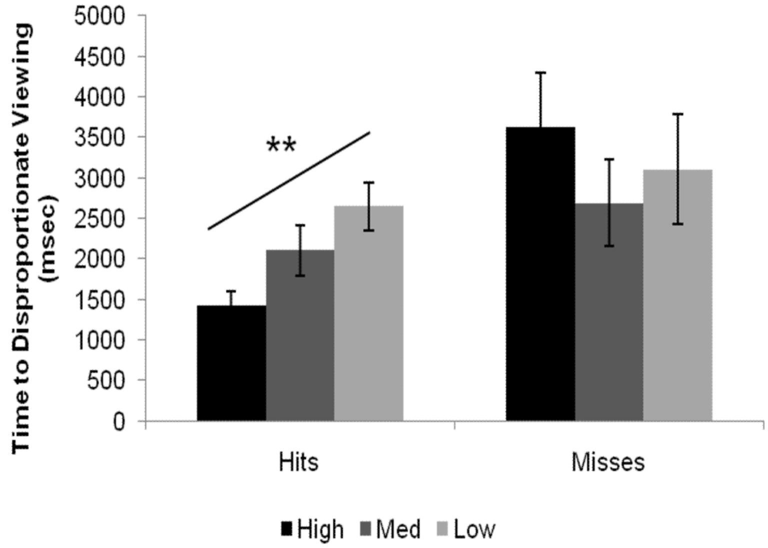

Figure 4.

Analyses of the time to disproportionate viewing suggest that, for accurate memory, confidence decisions are based in part on the speed to retrieval. For Hits, participants showed disproportionate viewing of the chosen face earlier for higher levels of confidence (** $p<0.002$, linear effect).

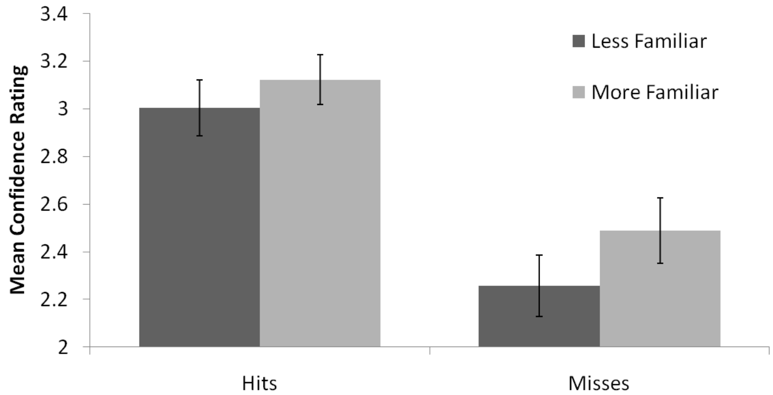

Figure 5.

A frequency manipulation showed higher confidence for scene-face associative recognition when the scene cue was more familiar, especially for incorrect recognition decisions.

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Table 1

Bin sizes and response times (RT) for correct and incorrect trials broken down as a function of confidence.

	Correct Trials			Incorrect Trials		
	Low	**Middle**	**High**	**Low**	**Middle**	**High**
Bin Size	3.58 (0.42)	4.08 (0.37)	10.8 (0.89)	6.08 (0.70)	4.29 (0.34)	3.79 (0.46)
RT (ms)	5356 (353)	5334 (301)	4253 (257)	5029 (277)	4964 (308)	4674 (258)