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Electrophysiological distinctions between recognition memory with and without awareness

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Abstract

The influence of implicit memory representations on explicit recognition may help to explain cases of accurate recognition decisions made with high uncertainty. During a recognition task, implicit memory may enhance the fluency of a test item, biasing decision processes to endorse it as “old”. This model may help explain recognition-without-identification, a remarkable phenomenon in which participants make highly accurate recognition decisions despite the inability to identify the test item. The current study investigated whether recognition-without-identification for pictures elicits a similar pattern of neural activity as other types of accurate recognition decisions made with uncertainty. Further, this study also examined whether recognition-without-identification for pictures could be attained by the use of perceptual and conceptual information from memory. To accomplish this, participants studied pictures and then performed a recognition task under difficult viewing conditions while event-related potentials (ERPs) were recorded. Behavioral results showed that recognition was highly accurate even when test items could not be identified, demonstrating recognition-without identification. The behavioral performance also indicated that recognition-without-identification was mediated by both perceptual and conceptual information, independently of one another. The ERP results showed dramatically different memory related activity during the early 300 to 500 ms epoch for identified items that were studied compared to unidentified items that were studied. Similar to previous work highlighting accurate recognition without retrieval awareness, test items that were *not identified*, but correctly endorsed as “old,” elicited a negative posterior old/new effect (i.e., N300). In contrast, test items that were *identified* and correctly endorsed as “old,” elicited the classic positive frontal old/new effect (i.e., FN400). Importantly, both of these effects were elicited under conditions when participants used perceptual information to make recognition decisions. Conceptual information elicited very different ERPs than perceptual information, showing that the informational wealth of pictures can evoke multiple routes to recognition even without awareness of memory retrieval. These results are discussed within the context of current theories regarding the N300 and the FN400.

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Keywords

recognition memory; familiarity; implicit recognition; implicit memory; recognition-without-identification

1. INTRODUCTION

Long-term memory has been classically divided into explicit and implicit memory (Squire & Zola, 1996). Explicit memory is commonly assessed by intentional learning tasks and direct tests like recognition, where participants view a test item and judge whether it was previously studied or not. In contrast, implicit memory is commonly assessed by incidental learning tasks and indirect tests that make no reference to studied information, and unlike explicit memory, behavior on implicit memory tests can accurately indicate evidence of memory without a subjective sense that the test information was previously studied. In other words, implicit memory retrieval lacks retrieval awareness. Although the dissociation between explicit and implicit memory has long been supported (Graf, Squire & Mandler, 1984; Verfaellie, Bauer & Bowers, 1991; Paller & Kutas, 1992; Rugg et al., 1998), less is known about how the two kinds of memory interact (Dew & Cabeza, 2011). Certainly, previous work has shown that tasks targeting explicit memory can be influenced by implicit memory and vice versa (Jacoby & Dallas, 1981; Verfaellie & Cermak, 1999; Voss, Baym & Paller, 2008). For this reason, it is important to understand how different memory systems inform decision-making related to memory.

The influence of implicit memory on explicit memory decisions may help to explain three effects in the memory literature in which recognition decisions are made with varying levels of uncertainty. First, *familiarity* is a subjective sense of having previously encountered an item without any available recollected details to assure certainty of its studied or unstudied status. Familiarity has been characterized within a signal detection framework as a measure of memory strength along a continuum, and items associated with high levels of subjective familiarity allow for fairly accurate recognition decisions (Yonelinas, Aly, Wang & Koen, 2010). Second, recognition decisions can also be highly accurate even when participants report that they are guessing, an effect called *implicit recognition* (Voss, Baym & Paller, 2008; Voss & Paller, 2009). In these studies, participants were instructed to “guess” when they had no confidence of memory, indicating a high level of uncertainty with little or no sense of familiarity or retrieval awareness. Finally, recognition decisions can be accurate even when the test item cannot be identified, an effect called *recognition-without-identification* (Cleary & Greene, 2001; 2005). Presently, the cognitive processes that underlie recognition-without-identification remain unclear, but we speculate that levels of retrieval awareness, certainty, and familiarity remain at their lowest because test items are not identified. Previous research has investigated the neural activity related to familiarity (Rugg & Curran, 2007; Rugg et al., 1998; Woodruff, Hayama & Rugg, 2006), implicit recognition (Voss & Paller, 2009), and more recently, recognition-without identification for *words* (Ryals, Yadon, Nomi & Cleary, 2011). The objective of the current study was to understand neural activity related to recognition-without-identification for *pictures*. Primarily, we wanted to understand whether recognition-without-identification for pictures evoked similar ERP activity as that associated with implicit recognition or that associated with familiarity. Since pictures convey a rich amount of information, we were also interested in whether recognition-without-identification for pictures was primarily based on perceptual or conceptual information, and whether it would evoke distinct neural patterns of activity depending on the kind of information used during retrieval.

How does an underlying implicit memory representation, which is generally not accompanied by awareness of previous exposure, influence explicit memory decisions? One popular model, the fluency heuristic model, proposes that when a test item on a recognition task is relatively easy to process, participants often attribute this experience of *processing fluency* to having previously studied the test item (Jacoby & Dallas, 1981). Under conditions of uncertainty, the sense of fluency can lead to accurate responses when the item activates a previous implicit memory representation (Jacoby & Dallas, 1981; Whittlesea, 1993; Conroy, Hopkins & Squire, 2005). However, fluency can also lead to significant false recognition (Jacoby & Whitehouse, 1989), particularly when test items create high levels of subjective fluency by activating associative conceptual or semantic networks (Karpicke, McCabe, & Roediger, 2008). Previous research has shown that the use of fluency heuristics often leads to recognition judgments based purely on familiarity (Rajaram, 1993). *Familiarity* is an acontextual, vague subjective sense that an item has been seen before, and stands in contrast to *recollection*, which is a vivid, contextually-bound form of recognition (Yonelinas, 2002). Electroencephalogram (EEG) measures have shown that familiarity strength modulates a negative-going frontal event-related potential (ERP) called the FN400 by evoking more positive activity for test items reported as “old” compared to those reported as “new” (Ally & Budson, 2007; Rugg & Curran, 2007; Rugg et al., 1998; Woodruff, Hayama & Rugg, 2006). However, the relationship between familiarity and the FN400 has become controversial, as some investigators have linked the FN400 with conceptual implicit memory (Voss, Lucas & Paller, 2010; 2012). This controversy will be discussed in more detail below as it relates to our hypotheses.

The fluency heuristic model may also help to explain the phenomenon of *implicit recognition*, which is highly accurate guessing during recognition decision-making (Voss, Baym & Paller, 2008; Voss & Paller, 2009). As an example, Voss and Paller (2009) had participants study abstract “kaleidoscope” images under full or divided attention. At test, participants performed a two-alternative forced-choice recognition task and followed their choice with a subjective “remember”, “know”, or “guess” response to indicate whether their choice was based on recollection, familiarity, or a guess lacking retrieval awareness, respectively. ERPs recorded at test showed distinct old/new effects depending on these subjective ratings of awareness. “Know” and “remember” responses to studied items compared to new items evoked positive activity in both early (180–220 ms) and late (600–900 ms) epochs over frontal and parietal areas. In contrast, correctly “guessed” items evoked a greater *negativity* compared to new items between 200–400 ms (N300) over occipital areas. Voss and Paller (2009) proposed that these ERP findings indicated distinct neural bases for recognition driven by explicit memory accompanied by retrieval awareness and implicit memory lacking retrieval awareness. Voss and colleagues (2008; 2009) further proposed that, during the forced-choice recognition, the higher perceptual fluency of studied items relative to unstudied items influenced participants to choose studied items as “old” even if they were unaware of previously viewing either item. This account is similar to how fluency can lead to familiarity judgments, except that instead of a weak sense of retrieval, participants lacked awareness at retrieval.

Our final example of how implicit memory influences explicit memory decisions, recognition-without-identification, describes accurate recognition of a test item even when it cannot be identified by the participant. As an example, Cleary and Greene (2005) had participants study a word list and then view test items that were rapidly presented and masked. These conditions rendered a large portion of test items unidentifiable but, remarkably, recognition responses were highly accurate, even for the test items that participants reported as unidentifiable. Like familiarity and implicit recognition, accurate recognition-without-identification may be driven by enhanced fluency of studied test items under very high levels of uncertainty. In accordance with this account, Cleary and Greene

(2001; 2005) have suggested that recognition-without-identification is mediated by the same process as familiarity, based on behavioral research showing recognition-without-identification to be observed under the same conditions that give rise to familiarity. However, Ryals, Yadon, Nomi and Cleary (2011) recently demonstrated that recognition-without-identification for words elicited ERP waveforms that were distinct from the FN400 typically associated with familiarity. Instead, they found that unidentified words that were studied elicited more negative activity than unidentified words that were unstudied around 300 ms post-stimulus onset in the right frontal and left occipital regions, similar to the N300 ERP effect of implicit recognition found by Voss and Paller (2009). This finding suggested that recognition-without-identification for words is mediated by a process very similar to that underlying implicit recognition, but very different from that underlying familiarity.

Our review of the literature on familiarity, implicit recognition, and recognition-without-identification shows that they commonly elicit memory-related (old/new) ERP effects within the 200–500 ms epoch, but with differing scalp topographies. Importantly, this common time course overlaps with the time course of implicit memory, and supports the possibility that familiarity, implicit recognition, and recognition-without-recognition are mediated by implicit memory representations. On a word recognition task, Rugg and colleagues (1998) found that, regardless of whether a word was recognized, old words evoked more positive activity than new words over posterior scalp areas at 300–500 ms. Similar findings were made by Woollams and colleagues (2008), who showed more positive activity over occipital areas for unrecognized old words compared to new words at 300–500 ms. In both studies, early ERP activity discriminated between old and new items despite participants' failure to discriminate them behaviorally, indicating implicit memory that was distinct from explicit memory. To more confidently separate implicit from explicit memory representations, Paller et al. (2003) distinguished between studied faces in memory that led to priming and those that led to explicit recognition. Primed-but-not recognized faces elicited more negative activity in frontal areas than new faces around 200–400 ms. It is possible that the early implicit memory representations found in these studies may be similar to the representations activated in familiarity, implicit recognition, and recognition without-identification.

In the current study, we set out to investigate whether recognition-without-identification for *pictures* evoked similar activity as other forms of recognition accompanied by decisional uncertainty, such as familiarity, implicit recognition, and recognition-without-identification for words. For example, it is unclear whether recognition-without-identification for pictures recruits the same processes as recognition-without-identification for words since picture recognition does not necessitate full identification (e.g., fragment recognition, Snodgrass & Feenan, 1990). Accurate recognition-without-identification could be based on a visual feature, like the shape of a sail on a sailboat (Cleary, Langley & Seiler, 2004). In this example, a participant might be aware of having studied a similar shape, but the information extracted at test would not be sufficient for identification. We hypothesized that recognition-without-identification for pictures would evoke the early negative N300 old/new ERP effect recorded over occipital scalp areas associated with implicit recognition and recognition-without-identification of words (Ryals et al., 2011; Voss & Paller, 2009). Conversely, we hypothesized that recognition-*with*-identification would evoke the early positive FN400 old/new ERP effect recorded over mid-frontal scalp areas associated with familiarity (Rugg et al., 1998; Rugg & Curran, 2007; Woodruff, Hayama & Rugg, 2006). It should be noted however, that recent work has shed doubt on whether the FN400 effect indexes familiarity per se. Voss and colleagues (Voss & Paller, 2007; Voss, Lucas & Paller, 2010, 2012) have argued that the FN400 may instead signal conceptual implicit memory that frequently co-occurs with judgments of familiarity. In one supportive example, Voss, Lucas and Paller (2010) showed that FN400 modulation only occurred for familiar items that produced conceptual priming, but not for familiar items that did not produce conceptual priming.

Rather than being associated with the FN400, familiarity judgments modulated the late positive complex (LPC), a positive old/new effect observed over parietal areas between 500–700 ms. This view differs greatly from the more traditional view built on a wealth of research linking familiarity to the FN400 (Ally & Budson, 2007; Rugg et al., 1998; Rugg & Curran, 2007; Woodruff, Hayama & Rugg, 2006). To accommodate both views, we predicted that recognition-*with*-identification for pictures would evoke positive old/new effects of the FN400 and/or the LPC.

We also speculated that recognition-without-identification for pictures is mediated by both perceptual and conceptual information. Compared to word stimuli, pictures can provide a wealth of information that could lead to different routes to recognition, including distinctive perceptual details (Mintzer & Snodgrass, 1999) and conceptual information (Hamilton & Geraci, 2006). This idea is captured by accounts like fuzzy trace theory (Brainerd & Reyna, 2002) and Marsolek's dual routes to recognition (1999) that propose that recognition can be mediated by the perceptual details of a studied items as well as the basic conceptual gist of the studied item. Supporting this assertion, previous research had shown that the explicit recognition of pictures relies on different cognitive processes and old/new ERP effects than words (Ally & Budson, 2007; Ally, Waring, et al., 2008; Curran & Doyle, 2011). To examine the contribution of perceptual and conceptual information to recognition-without-identification, we followed a similar method used by Langley, Cleary, Kostic and Woods (2008). At test, participants viewed *Studied* pictures, *Exemplar* pictures drawn from the same basic-level categories as the studied pictures, or novel *Unstudied* pictures. The recognition of a Studied picture would be mediated by an item-specific representation that encompasses the perceptual and conceptual information related to that Studied picture. The false recognition of an Exemplar picture would be mediated by a category-wide representation that encompasses only the conceptual information shared by all category members of a Studied picture (e.g., all dogs have four legs), but do not perceptually match a particular Studied picture (Marsolek, 1999). Critically, the use of perceptual information could be found by finding the *difference* in behavior and ERP activity between the Studied pictures and Exemplar pictures, while the use of conceptual information could be found by finding the difference in behavior and ERP activity between Exemplar pictures and Unstudied pictures. We hypothesized that old/new ratings made during recognition-without-identification would discriminate between Studied and Exemplar items, as well as between Exemplar and Unstudied items.

2. METHODS

2.1 Participants

Twenty young adults were recruited into the experiment, including 11 females, with a mean age of 22 years (standard deviation, $s = 2.8$ years) and an average of 16.8 years of formal education ($s = 4.3$ years). All participants were right-handed and native English speakers. The data from four participants were excluded in the final analysis because of low trial counts due to excessive EEG artifact. All participants gave written informed consent before participating and were paid \$25 per hour. This study was approved by the Behavioral and Social Sciences Committee of the Vanderbilt University Institutional Review Board.

2.2 Stimuli and Apparatus

The stimuli were 264 black and white line drawings of common items. Half of these pictures were pairs of items from the same basic-level category, i.e. dogs, which we refer to as "categorical pairs." The other half did not share basic-level categories with any other pictures, which we referred to as "unique." The use of each unique item as a Studied item or an Unstudied item during the Test phase was counterbalanced across participants. The use of

each member of a categorical pair as a Studied item or an Exemplar item during Test was also counterbalanced across participants.

Sixty-six different basic level categories were used (e.g., dogs, trains, birds, forks; examples can be viewed in Figure 1). Because members of the same category share important visual features, it is possible that items from the same category were more visually similar to each other than to items from different categories. To fully understand the visual similarity in our picture set, we used Zelinsky's (2003) bank of local analyzer responses (BOLAR) method to measure the visual similarity within categories and across categories. This method represents each picture as a pattern of responses, or BOLAR vector, from a set of filters sensitive to a range of spatial frequencies and orientations. The visual similarity between two stimuli is considered to be the linear difference between their respective BOLAR vectors. This *difference vector* can then be summarized into single index by squaring each signal, summing them, and then taking the square root of that value. Finally, these scores are normalized relative to the entire set of pictures in the analysis by dividing each score by the largest difference found in the set and subtracting the scores from 1. The resulting index ranges from 0 to 1 with low values indicating low similarity and high values indicating high similarity (i.e., a score of 1 would be given to two identical images). This analysis was applied to our set of categorical pairs. Each exemplar in a categorical pair was compared to its counterpart exemplar (within category) and every other item outside of its category (across category). The mean of within-category comparison scores (mean = 0.60, $s = 0.13$) was not significantly different than that of across-category comparison scores (mean = 0.59, $s = 0.11$), $t(4354) = 1.01$, $p = 0.31$ (Figure 1). The lack of a significant difference between within-category and across-category comparison scores indicated that the exemplar items were as visually different from their categorical counterparts as other items in the picture set.

The stimuli were presented with E-Prime 2.0 on a Dell computer and appeared on the screen within an area of $15^\circ \times 15^\circ$ visual angle. Participants viewed the stimuli on a 53 centimeter (cm) flat screen computer monitor positioned at a distance of 122 cm.

2.3 Behavioral Procedure

Each participant completed three separate Study-Test blocks. Each block consisted of 44 pictures during the Study phase and 66 pictures during the Test phase. The pictures presented at Test included 22 *Studied* pictures, 22 *Unstudied* pictures, and 22 *Exemplars*, which were unstudied pictures drawn from the same basic-level category as the Studied pictures. Following Langley et al. (2008), this manipulation allowed us to observe whether performance was facilitated by perceptual or conceptual information. Performance benefits related to the Exemplar items compared to Unstudied items (Exemplar – Unstudied) were considered to result from the overlap of conceptual information shared by members of the same basic categories. Additional benefits related to the Studied items compared to the Exemplar items (Studied – Exemplar) were considered to result from the perceptual information from Studied items.

During the Study phase, participants viewed a sequence of pictures. Each picture appeared for 3000 ms followed by a blank inter-stimulus interval (ISI) of 1000 ms. Participants were told to study the pictures for a subsequent memory test. The Test phase immediately followed. Each trial of the Test phase began with a 1000 ms fixation cross. This fixation was followed by a forward visual mask appearing for 100 ms. Next, a centrally presented picture appeared for 67 ms, which was then followed by a backward mask appearing for 100 ms. Previous work has shown that visual stimuli can be perceived at this brief duration (Nieuwenstein & Potter, 2006; Langley et al., 2008). After a 1000 ms blank ISI, a dialog box appeared at the center of the screen containing the phrase "Can you name the image?" Participants responded by pressing one of two keys marked "Yes" or "No". Participants

were encouraged to only indicate a “Yes” response if they could name the image with a high level of certainty. Otherwise, they were encouraged to select a “No” response. It should be noted that participants did not overtly name the picture following the “Yes/No” response because vocalization created significant unwanted noise in the EEG recording and minimized usable bin sizes for important comparisons. In contrast, this method potentially resulted in less pure ERPs since it did not allow us to verify whether the participants were truly accurate in their item identification. For example, “Yes” responses could have included trials when the participant thought she was correct and was accurate, as well as when she thought she was correct but was inaccurate. However, we instructed the participants to adopt a high criterion when making the “Yes/No” identification response. Additionally, the results of a similar behavioral pilot experiment with eight adults showed that naming responses following “Yes/No” response were highly accurate (>90%).

After issuing the “Yes/No” response, a second dialog box appeared on the screen that contained four response options. At this screen, participants rated their certainty that the picture had appeared previously during the Study phase or was a novel item that was not presented during the Study phase. These old/new ratings required selection of one of the following response options: “1” indicated a high certainty that the picture was New; “2” indicated a low certainty that the picture was New; “3” indicated a low certainty that the picture was Old; and “4” indicated a high certainty that the picture was Old. Participants were encouraged to use the full range of the scale. For Unidentified pictures, participants were encouraged to guess using the full range of the scale. Figure 2 illustrates the behavioral procedure.

2.4 ERP procedure

Participants were seated in a hardback chair and fitted with an Active Two electrode cap (Behavioral Brain Sciences Center, Birmingham, UK). A full array of 128 Ag-AgCl Biosemi (Amsterdam, Netherlands) “active” electrodes were connected to the cap in a pre-configured montage which places each electrode in equidistant concentric circles from 10–20 position Cz. Active electrodes are amplified through the electrode at the source and do not require abrading of the skin or measuring skin-electrode impedance levels. In addition to the 128 scalp electrodes, two mini-biopotential electrodes were placed on each mastoid process. Finally, vertical and horizontal electrooculogram (EOG) activity was recorded from bipolar electrodes placed below the left eye and on the outer canthus of the left and right eye. EEG and EOG activity was amplified with a bandwidth of 0.03–35 Hz (-3dB points) and digitized at a sampling rate of 256 Hz. Recordings were referenced to a vertex reference point, but were later rereferenced to a common average reference to minimize the effects of reference-site activity and accurately estimate the scalp topography of the measured electric fields (Ally & Budson, 2007; Curran, DeBuse, Woroch & Hirshman, 2006; Dien, 1998).

The sampling epoch for each test trial lasted for a total of 1300 ms, which included a 200 ms pre-stimulus baseline period. This pre-stimulus period was used to baseline correct averaged ERP epochs lasting 1100 ms. ERPs were averaged and corrected using the EMSE Software Suite (Source Signal Imaging, San Diego, CA, USA). Individual channels with poor signals were corrected with the EMSE spatial interpolation filter. Trials were corrected for excessive EOG activity using the EMSE Ocular Artifact Correction Tool. The tool first allows the investigator to manually distinguish artifact-containing data from artifact-free data. Then, using the covariance technique that simultaneously models artifact and artifact-free EEG, a logarithmic ratio of artifact data to clean data is produced by EMSE. Finally, ocular artifact is subtracted from the recording where it is detected by the correction tool. Trials were discarded from the analyses if they contained baseline drift or movement greater than 90 μ V.

3. RESULTS

3.1 Behavioral results

3.1.1 Proportion of pictures identified—Repeated measures analysis of variance (ANOVA) and follow-up contrasts confirmed a significant effect of Condition (Studied, Exemplar, Unstudied) on the proportion of items identified correctly [$F(2, 30) = 25.83, p < .001$] (Figure 3A). Participants correctly identified more Studied items than Unstudied [$t(15) = 6.80, p < .001$] and Exemplar [$t(15) = 3.84, p = .002$] items. Participants also correctly identified more Exemplar items than Unstudied items [$t(15) = 3.58, p = .003$].

3.1.2 Recognition measures—The behavioral data were first organized into Hits and False Alarms. Hits were correct “old” responses (ratings 3 and 4) to Studied items and False Alarms were incorrect “new” responses (ratings 1 and 2) to Exemplar or Unstudied items. Two versions of the recognition accuracy *Pr* (Proportion of Hits – proportion of False Alarms; Snodgrass & Corwin, 1988) were calculated: *Pr of Studied-Unstudied items (Pr-SU)* and *Pr of Studied-Exemplar items (Pr-SE)*. Both measures used the hit rate of Studied items, but *Pr-SU* used the proportion of false alarms to Unstudied items while *Pr-SE* used the proportion of false alarms to Exemplar items. These discrimination measures were calculated separately for Identified and Unidentified items (i.e., in calculating these values for Identified items, only Identified items were considered.) These discrimination measures were submitted to an ANOVA examining the effects of Identification status (Identified, Unidentified) $\times$ Discrimination (*Pr-SU*, *Pr-SE*), which revealed main effects of Identification and Discrimination (F -values > 23) and a significant interaction between these two factors [$F(1, 15) = 9.07, p = 0.009$]. Paired comparisons for the Identified items showed *Pr-SU* (0.37) to be significantly higher than *Pr-SE* (0.17) [$t(15) = 4.63, p < 0.001$] indicating a higher rate of false alarms to the Exemplar items compared to the Unstudied items. However, discrimination was very low in the Unidentified trials and there was no significant difference between *Pr-SU* (0.05) and *Pr-SE* (0.026) [$t(15) = 1.03, p = 0.31$].

To examine changes in confidence, we classified the recognition ratings into high (collapsing across ratings 1 and 4) and low (collapsing across ratings 2 and 3) confidence classes for all conditions. The proportion of High confidence responses were then submitted to an ANOVA examining the effects of Identification (Identified, Unidentified) $\times$ Condition (Studied, Exemplar, Unstudied). The results yielded main effects of Identification [$F(1, 15) = 10.4, p = 0.006$] and Condition, [$F(2, 30) = 4.88, p = 0.015$] as well as a significant interaction between these factors, [$F(2, 30) = 13.71, p < 0.001$]. In the Identified trials, paired comparisons revealed more High confidence responses for Studied items compared to Exemplar items [$t(15) = 5.1, p = 0.001$] and Unstudied items [$t(15) = 5.05, p = 0.001$]. There were no differences in confidence between Exemplar and Unstudied items [$t(15) = 0.34, p = 0.73$]. Also, there were no significant differences across conditions in the Unidentified trials (all t -values < 2). Notice that we would have yielded the same statistics if we chose to analyze the Low confidence responses since those values are yoked with the High confidence responses.

Since the differences in discrimination and confidence were not sensitive to changes in behavior to the Unidentified items, we used the average rating given to items in each condition following the methods of Langley et al. (2008). On the scale of old/new ratings, higher ratings reflected higher certainty that items were “old”. The average ratings for each condition (Studied, Exemplar, Unstudied) as a function of identification status (Identified, Unidentified) are depicted in Figures 3B and 3C. A repeated-measures ANOVA revealed main effects of Condition [$F(2, 30) = 114.30, p < .001$] and Identification Status [$F(1, 15) = 18.95, p = .001$] as well as an interaction of Condition and Identification Status [$F(2, 30) = 72.50, p < .001$]. Follow-up paired sample t -tests revealed that participants rated Studied-

Identified pictures higher than Unstudied-Identified [$t(15) = 15.07, p < .001$] and Exemplar-Identified pictures [$t(15) = 5.76, p < .001$]. Further, participants rated Exemplar-Identified pictures higher than Unstudied Identified pictures [$t(15) = 10.42, p < .001$]. Most interestingly, participants rated Studied-Unidentified pictures higher than Unstudied-Unidentified pictures [$t(15) = 2.95, p = .010$] and Exemplar-Unidentified pictures [$t(15) = 2.51, p = .024$]. This indicated that perceptual information was used during recognition-without-identification. Participants also rated Exemplar-Unidentified pictures higher than Unstudied-Unidentified pictures [$t(15) = 2.18, p = .046$], suggesting that conceptual information also contributed to recognition-without identification (see Figure 3).

3.2 ERP results

For the ERP analysis, the minimum number of trials per condition was set to 16 (Ally, 2011). The average trial count (range in parentheses) for each condition in the ERP analyses were: Studied-Identified = 40.25 (25–48), Unstudied-Identified = 23.69 (16–42), Exemplar-Identified = 31.88 (18–51), Studied-Unidentified = 24.81 (16–40), Unstudied-Unidentified = 41.19 (20–55), and Exemplar-Unidentified = 33.25 (16–47). As stated in the Methods (Section 2.1), four of the 20 subjects had bin sizes below 16 due to excessive EEG artifact and were not included in the analyses.

ERP activity was averaged within 10 spatial regions of interest (ROI). These regions included electrode locations corresponding to the following scalp areas (see Figures 4 and 5): left anterior inferior (LAI), central anterior inferior (CAI), right anterior inferior (RAI), left anterior superior (LAS), right anterior superior (RAS), left posterior superior (LPS), right posterior superior (RPS), left posterior inferior (LPI), central posterior inferior (CPI), and right posterior inferior (RPI). We focused our analysis on epochs during which ERP effects related to familiarity, implicit recognition, and recollection were known to occur. Specifically, ERP activity elicited from 300 to 500 ms post stimulus onset is typically associated with memorial familiarity (Ally & Budson, 2007; Curran, 2000; Rugg & Curran, 2007, but also see Voss, Lucas, & Paller, 2010). This early positive old/new effect is observed bilaterally over more frontal-superior recording sites (Rugg & Curran, 2007), so we expected to observe it in regions LAS and RAS during the 300–500 ms epoch. During this epoch we also targeted occipital areas (LPI, CPI, RPI) to detect activity previously elicited by implicit recognition (Voss & Paller, 2009). Additionally, we expected recollection related activity typically observed over parietal areas (LPS, RPS) during the 500 to 700 and 700 to 900 ms intervals (Ally & Budson, 2007; Ally, Simons, McKeever, Peers, & Budson, 2008; Paller, & Kutas, 1992; Rugg & Curran, 2007; Woodruff, Hayama, & Rugg, 2006). Previous research has suggested that the latter part of the late parietal effect (700–900) reflect changes to object form (Schendan & Kutas, 2003; 2007), which is relevant to the exemplar change effect in the current experiment. Data from these three epochs (300–500, 500–700, 700–900) were submitted separately to repeated measures ANOVA to examine factor effects of Condition (Studied, Exemplar, Unstudied), Identification Status (Identified, Unidentified) and ROI (LAI, CAI, RAI, LAS, RAS, LPS, RAS, LPI, CPI, RPI). Following the report of the ANOVA, we report only the significant paired contrasts for brevity. In all ANOVAs reported below, degrees of freedom associated with repeated measures factors were corrected for nonsphericity using the Greenhouse-Geisser correction. Partial eta squared (η_p^2) is reported as a measure of effect size.

3.2.1 300–500 ms—The ANOVA examining factors of Condition (Studied, Exemplar, Unstudied), Identification Status (Identified, Unidentified) and ROI (LAI, CAI, RAI, LAS, RAS, LPS, RAS, LPI, CPI, RPI) during the 300 to 500 ms interval revealed an effect of ROI [$F(9, 135) = 4.41, p = .035, \eta_p^2 = 0.227$], and interactions of Condition and ROI [$F(18, 270) = 3.80, p = .004, \eta_p^2 = 0.202$], Identification Status and ROI [$F(9, 135) = 5.95, p = .002, \eta_p^2 =$

= 0.284], as well as a three-way interaction of Condition, Identification Status, and ROI [$F(18, 270) = 2.61, p = .029, \eta_p^2 = 0.148$]. Follow-up paired sample t -tests revealed important differences in the *Unidentified* trials. Studied items were more positive than Unstudied items at right frontal region RAI [$t(15) = 2.64, p = .018$]. A dramatically different pattern was observed in posterior and occipital regions. Most importantly, at left parietal region LPS [$t(15) = 3.52, p = .003$] and left occipital region LPI [$t(15) = 3.20, p = .006$], Studied items elicited more negative ERP activity than Unstudied items. At occipital region LPI, Studied items elicited more negative ERP activity than Exemplar items, but this difference only approached significance [$t(15) = 2.01, p = .060$]. This activity was very similar to the component associated with implicit recognition Voss and Paller (2009) and recognition without-identification for words (Ryals et al., 2011). Finally, Exemplar items elicited a more negative going ERP than Unstudied items at right parietal region RPS [$t(15) = 2.45, p = 0.027$], perhaps suggesting that some component of implicit recognition may be based on conceptual information. The topographies for each contrast are depicted in Figure 6 and waveforms are depicted in Figure 7.

Paired comparisons also found ERP differences when the items were *Identified* during the 300 to 500 ms epoch. In frontal regions CAI, LAS, and RAS, Studied items elicited more positive activity than both Unstudied items (CAI [$t(15) = 2.20, p = .044$], LAS [$t(15) = 3.24, p = .006$], RAS [$t(15) = 3.07, p = .008$]) and Exemplar items (CAI [$t(15) = 2.47, p = .026$], LAS [$t(15) = 3.79, p = .002$], RAS [$t(15) = 3.04, p = .008$]). Previous research has typically implicated these regions in memorial familiarity (Ally & Budson, 2007; Rugg & Curran, 2007; Woodruff, Hayama & Rugg, 2006), although a recent study claims that this activity actually reflects conceptual fluency (Voss, Lucas & Paller, 2010). However, the old/new effects observed in these regions were likely based on perceptual information since Studied items were more positive than both Exemplar and Unstudied items and no difference in activity was observed between the Exemplar and Unstudied items. Occipital regions showed a different pattern than frontal regions. Studied items elicited more negative activity than Exemplar items in regions LPI [$t(15) = 2.98, p = 0.009$], CPI [$t(15) = 4.32, p = 0.001$, and RPI [$t(15) = 5.077, p < 0.0001$]. Additionally, Studied items elicited more negative activity than Unstudied items in region RPI [$t(15) = 2.93, p = 0.01$].

3.2.2 500 to 700 ms—The ANOVA for the 500–700 ms epoch revealed a trend towards an effect of ROI [$F(9, 135) = 3.32, p = .06, \eta_p^2 = 0.181$]. Additionally, there were interactions of Condition and ROI [$F(18, 270) = 2.95, p = .014, \eta_p^2 = 0.164$], Identification Status and ROI [$F(9, 135) = 3.53, p = .034, \eta_p^2 = 0.19$], as well as a three-way interaction of Condition, Identification Status, and ROI [$F(18, 270) = 2.53, p = .047, \eta_p^2 = 0.145$]. Follow-up paired sample t -tests revealed important differences in the *Unidentified* trials. Here, Studied items elicited more positive ERP activity at inferior right frontal region RAI than Unstudied items [$t(15) = 2.33, p = .034$] and Exemplar items [$t(15) = 2.59, p = .021$]. In contrast, Studied items elicited more negative going ERPs than Unstudied items at posterior regions CPI [$t(15) = 2.47, p = .026$] and LPI [$t(15) = 2.38, p = .031$]. Similarly, Studied items elicited more negative ERP activity than Exemplar items at posterior regions CPI [$t(15) = 2.33, p = .034$] and LPI [$t(15) = 2.61, p = .020$].

In the *Identified* trials, we again found significant old/new effects during the 500 to 700 ms time interval. Frontal regions LAS and RAS again showed more positive activity for Studied items compared to Unstudied items (LAS [$t(15) = 3.72, p = .002$] and RAS [$t(15) = 2.36, p = .032$]) and compared to Exemplar items (LAS [$t(15) = 2.02, p = .061$] and RAS [$t(15) = 2.82, p = .013$]). In parietal region LPS, Studied items evoked more positive activity than Unstudied items, [$t(15) = 2.58, p = .021$]. Also in LPS, there was a trend of Exemplar items evoking more positive activity than Unstudied items, [$t(15) = 1.99, p = 0.06$]. This activity resembled the LPC known to mediate memorial recollection (Rugg & Curran, 2007),

although it was been also recently linked to familiarity (Voss, Lucas & Paller, 2010). In contrast to the positive old/new effects over frontal and parietal areas, negative old/new effects were found over occipital areas. Specifically, Studied items were more negative than Exemplar items in regions LPI [$t(15) = 2.60, p = .02$], and RPI [$t(15) = 4.09, p = .001$]. Also, Studied items were more negative than Unstudied items in region LPI, [$t(15) = 2.73, p = 0.015$].

3.2.3 700 to 900 ms—The ANOVA for the 700 to 900 ms interval revealed an effect of ROI [$F(9, 135) = 11.49, p < 0.0001, \eta_p^2 = 0.434$], and a three-way interaction of Condition, Identification Status, and ROI [$F(18, 270) = 2.86, p = .014, \eta_p^2 = 0.16$]. Follow-up paired samples t -tests did not show any differences in ERP activity for Unidentified items. However, there were significant old/new effects in the Identified trials. Frontal region LAS continued to show the same pattern as in earlier epochs with Studied items evoking more positive activity than Unstudied items [$t(15) = 2.26, p = .039$] and Exemplar items [$t(15) = 2.44, p = .028$]. Frontal region RAS also showed more positive activity for Studied items compared to Exemplar items, [$t(15) = 2.55, p = .022$], but in this region, Unstudied items showed more positive activity than Exemplar items, [$t(15) = 2.16, p = .048$]. Left parietal region LPS showed more positive activity for Studied items compared to Unstudied items, [$t(15) = 4.18, p = .001$]. Importantly, region LPS showed a graded activity between all three conditions with the most positive activity for the Studied items, followed by that of the Exemplar items, and then the Unstudied items. This pattern was supported by contrasts showing more positive activity for Studied items compared to Exemplar items, [$t(15) = 3.10, p = .007$] and more positive activity for exemplar items compared to unstudied items, [$t(15) = 2.31, p = .036$]. Parietal region RPS also showed a trend for Studied items evoking more positive activity than Unstudied items, [$t(15) = 2.075, p = 0.056$]. Finally, in occipital region RPI, Studied items showed more negative activity than Exemplar items, [$t(15) = 3.99, p = 0.001$].

3.2.4 Correct trials only—To establish a better correspondence with previous research examining old/new ERP effects, we analyzed ERPs for trials with accurate responses only. The minimum ERP bin sizes were set to 16, resulting in the exclusion of 6 participants and limiting our analysis to the Identified trials. “Old” trials included accurate responses to Studied items (i.e., Hits; average bin size = 37.5 trials, range = 29 – 51) and “New” trials included accurate responses to Unstudied items (i.e., correct rejections; average bin size = 25.5 trials, range = 17 - 40). Low bin sizes did not allow a separate analysis using Exemplar items as the “New” trials. We first analyzed ERPs during the 300–500 and 500–700 ms epochs. The average ERP magnitudes of the 300–500 ms epoch were submitted to an ANOVA examining the effects of ROI (LAI, CAI, RAI, LAS, RAS, LPS, RPS, LPI, CPI, RPI) $\times$ Response (Old, New). There was no main effect of ROI [$F(9,81) = 3.14, p = 0.1$] or Response [$F(1,9) = 0.21, p = 0.65$], and there was no interaction between these factors [$F(9, 81) = 1.5, p = 0.23$]. Next, the average ERP magnitudes during the 500–700 ms epoch were submitted to the same ANOVA, but no main effects or interactions were observed (all p -values > 0.1).

Although our analyses did not reveal old/new effects during the 300–500 ms and 500–700 ms epochs, visual inspection of the topographies suggested important old/new effects during the 600–800 ms epoch (Figure 6). The averaged ERP magnitudes from the 600–800 epoch were then submitted to the ROI $\times$ Response ANOVA. The results did not show main effects of ROI [$F(9,81) = 2.63, p = 0.12$] or Response [$F(1,9) = 0.08, p = 0.78$], but there was a significant ROI $\times$ Response interaction [$F(9,81) = 3.73, p = 0.02, \eta_p^2 = 0.29$]. Paired comparisons showed significant positive old/new effects in regions LAS [$t(9) = 4.64, p = 0.001$], RAS [$t(9) = 4.24, p = 0.002$], and LPS [$t(9) = 6.82, p < 0.001$]. There was also a negative old/new effect in region RAI [$t(9) = 2.66, p = 0.026$]. The activity found in this

analysis is consistent with the findings of the previous analysis during the 500–700 ms epoch. However, while the previous analysis of the 500–700 ms epoch showed a negative old/new effect in the occipital region (RPI), it was not present in the current analysis.

4. DISCUSSION

The current study examined three broad hypotheses related to recognition-without identification of pictures. First, we hypothesized that recognition-without-identification for pictures would evoke similar neural activity as other forms of recognition that involve decisions made with high uncertainty. This prediction was confirmed by our results, which showed that recognition-without-identification for pictures evoked an N300 old/new effect over occipital areas, similar to that of implicit recognition (Voss & Paller, 2009) and recognition-without-identification of words (Ryals et al., 2011). Second, we hypothesized that recognition-*with*-identification would show ERP activity that was qualitatively different from recognition-without-identification, but was similar to classic old/new activity observed in studies of explicit recognition memory (Rugg & Curran, 2007; Woodruff et al., 2006). This hypothesis was also confirmed as ERP activity for successfully identified test items showed classic positive old/new effects in frontal regions during the FN400 time interval and in parietal regions during the LPC time interval. Finally, based on our speculation that recognition-without-identification for pictures is mediated by both perceptual and conceptual information, we hypothesized that behavior and ERP activity related to recognition-without-identification would discriminate between Studied and Exemplar items, which differ perceptually, as well as between Exemplar and Unstudied items, which differ conceptually. These predictions were confirmed both in the behavioral and ERP results, suggesting that recognition-without-identification of pictures is mediated by both perceptual and conceptual information.

4.1 Neural activity related to recognition-without-identification for pictures

The primary finding of our study was that recognition-without-identification for pictures evoked ERP activity similar to that evoked by implicit recognition (Voss & Paller, 2009) and recognition-without-identification for words (Ryals et al., 2011). Specifically, ERP activity during the Unidentified trials showed more negative activity for Studied items than Unstudied and Exemplar items over occipital recording sites between 300–500 ms post-stimulus onset, an effect that Ryals et al. (2011) called the N300. The N300 observed during recognition-without-identification was accompanied by a positive old/new effect observed in the right anterior inferior region, specifically revealed by the Studied – Exemplar contrast. Although studies of familiarity consistently show positive old/new effects in frontal areas during the 300–500 ms epoch (Rugg & Curran, 2007; Woodruff et al., 2006), they are usually found in more superior and bilateral frontal areas. The topographical distinctions between our finding and the ERP correlates of familiarity in the literature sheds some doubt that the right anterior inferior effect reflects familiarity. However, some research showing neural correlates of familiarity with atypical topographical distributions (Wolk et al., 2004; Lucas, Taylor, Henson & Paller, 2012) suggests that it is possible. The positive old/new effect in the right anterior inferior region may reflect a form of familiarity that is specific to the perceptual identification task that we used to elicit recognition-without-identification rather than recognition-without-identification itself. Another possibility is that this right anterior inferior old/new effect reflects the inversion of the dipole generating the N300 over (left) occipital areas.

The relationship found between recognition-without-identification for pictures and the N300 over occipital areas has several implications. First, finding N300 activity in recognition without-identification for both pictures and words (Ryals et al., 2011) as well as implicit recognition (Voss & Paller, 2009) suggests that the N300 is not specific to any stimulus

format (e.g., pictures versus words) and may be a common memory signature across different paradigms eliciting recognition without retrieval awareness. Second, the absence of old/new effects on the FN400 and the LPC during the Unidentified trials suggests that recognition without-identification is distinct from explicit familiarity-based recognition, counter to some previous claims (Cleary & Greene, 2001; 2005; Langley et al., 2008). Based on the electrophysiological comparison with other recognition phenomena known to lack retrieval awareness, we speculate that recognition-without-identification for pictures also lacks retrieval awareness. What remains less clear is what these ERP results indicate about the process underlying recognition-without-identification for pictures, but interesting possibilities are explored below.

4.2 What does the N300 represent?

Since Voss and Paller (2009) carefully excluded explicit recognition and used abstract visual stimuli in their paradigm, they suggested that the N300 activity represented perceptual implicit memory (or enhanced perceptual fluency) that was used to make a recognition decision under uncertainty. Ryals et al. (2011) also found the N300 in association with recognition without-identification for words, and as with Voss and Paller's (2009) study, they took methodological steps to ensure that participants lacked awareness of retrieval at test. The careful separation of awareness and unawareness of retrieval in both of these studies lend support to the claim that the N300 evoked in the unaware trials reflects a form of unconscious recognition, perhaps driven by perceptual implicit memory. In support of the claim that the N300 reflects activity that is perceptual, or item-specific, rather than conceptual in nature, we found the N300 in the difference between the Studied and Exemplar items, but not between the Exemplar and Unstudied items. However, it should be noted that our original analysis showed the N300 during both Identified and Unidentified trials, potentially placing some doubt that it exclusively occurs with unconscious recognition memory. It is possible that during the Identified trials, the presence of the N300 in conjunction with the FN400 and the LPC reflected the use of perceptual implicit memory in a qualitatively different manner than that of the Unidentified trials. For example, the perceptual implicit representation that is reflected in the N300 could ultimately result in retrieval awareness and subsequent feeling of familiarity or recollection. Alternatively, the N300 during the Identified trials could have reflected activity to items erroneously identified. In support of this latter view, our subsequent analysis that removed false alarms from the Identified trials also removed the N300 (see Section 3.2.4). Overall, our results support the idea that the N300 reflects perceptually-based activity, but further work is necessary to examine whether it is exclusively activated for recognition without retrieval awareness.

4.3 What does the FN400 represent?

Although the FN400 has long been associated with familiarity (Ally & Budson, 2007; Rugg & Curran, 2007; Woodruff, Hayama & Rugg, 2006), Voss and colleagues have raised the possibility that it actually reflects conceptual implicit memory that often co-varies with familiarity (Voss, Lucas & Paller, 2010; 2012). Interestingly, our experimental design allowed us to comment on this debate. The claim that the FN400 reflects conceptual implicit memory predicts that we would have observed it during the Unidentified trials, specifically with the Exemplar – Unstudied contrast. Memory effects observed during the Unidentified trials were arguably mediated by implicit memory representations, and the Exemplar – Unstudied contrast was specifically designed to reveal activity related to memory based on the conceptual information (Langley et al., 2008). However, the FN400 was absent during these trials, which instead revealed a right parietal negativity (to be discussed below). Counter to the view that the FN400 reflects conceptual implicit memory, the more traditional view that it reflects familiarity-based recognition predicts that we would have

observed it during the Identified trials, specifically with an old-new subtraction. This was confirmed in our results as the FN400 was observed in Identified trials, specifically with Studied – Unstudied and Studied – Exemplar contrasts. Interestingly, the observation of the FN400 during trials that we expected to be mediated primarily by perceptual information (Studied – Exemplar) may suggest that our participants used a form of familiarity that is sensitive to the item-specific or perceptual aspects of memory. Previous research has hinted that such a form of familiarity might exist, showing larger FN400 effects when study and test items matched in presentation modality (Ecker, Zimmer & Groh-Bordin, 2007; Ally & Budson, 2007; Curran & Doyle, 2011), or showing an absence of the FN400 for large perceptual mismatches between studied items and their corresponding test items (Tsivilis, Otten & Rugg, 2001).

However, we remain open to the possibility that our observation of the FN400 during the Identified trials reflected activation of conceptual implicit representations. Beyond the conceptual overlap shared with Exemplar items, Studied items may have also contained exclusive conceptual information. For example, a picture of a four-door sedan might share a lot of conceptual information with a picture of a two-car sports car, but it uniquely conveys the concept of “four doors.” Therefore, it is possible that the FN400 modulation that we observed reflected the concepts unique to the Studied items. If modulation of the FN400 does reflect the activation of a conceptual implicit representation, our observation of the FN400 during the Identified trials does not imply that conceptual implicit memory is necessarily accompanied by retrieval awareness. Another component of Voss and colleagues' hypothesis (2010, 2012) is that familiarity is indexed by the late parietal effect (i.e., LPC), not the FN400. It is possible that our observation of the FN400 reflected conceptual implicit memory, but retrieval awareness did not occur during this early epoch (300–500 ms). Instead, the activation of conceptual implicit memory during the early epoch informed familiarity or recollection processes at the later epoch (500–700 ms) when we observed the late parietal effect. Importantly, this proposed process is consistent with the view that familiarity entails enhanced fluency that later informs an attribution process (Jacoby & Whitehouse, 1989). Though our results lend support to the hypothesis that the FN400 reflects explicit familiarity, we currently consider the role of FN400 controversial since our results can potentially accommodate alternative views.

4.4 Perceptual and conceptual contributions to recognition-without-identification

Some theories have proposed that recognition could be served by multiple types of information, including item-specific perceptual information and gist-based conceptual information (Marsolek, 1999; Brainerd & Reyna, 2002). Based on these theories, we hypothesized that behavior during the Unidentified trials would discriminate between Studied and Exemplar items, suggesting the use of item-specific perceptual information, and also discriminate between Exemplar and Unstudied items, suggesting the use of category-wide conceptual information. Both of these predictions were confirmed in our results. The finding of higher ratings for the Studied items compared to Exemplar items was consistent with a previous study of recognition-without-identification for pictures (Langley et al., 2008). However, the finding that Exemplar items were rated higher than Unstudied items runs somewhat counter the results of Langley et al. (2008), who reported no difference in recognition ratings between these item types. One reason for this divergence could be a methodological difference between the two studies. While Langley et al. (2008) separated the Studied and Exemplar items across different blocks, the current study intermixed these items within test blocks. It is possible that blocking of these item types made the perceptual differences between Studied and Exemplar more salient, leading to Exemplar items being treated like Unstudied items. Conversely, intermixing the Studied and Exemplar items in the same blocks as we did could have increased the confusability between the two item types

because of their visual similarity. A similar explanation for the conceptual effect in our behavioral results is that the perceptual similarity between the Studied items and Exemplar items lured participants into endorsing Exemplar items as “old”. Both of these accounts assume that the visual similarity between the items within the same category (Studied and Exemplar items) is significantly greater than items across category. However the BOLAR analysis (Section 2.2; Zelinsky, 2003) disconfirmed this possibility, ruling out both accounts. Finding significant differences in the ratings between Studied and Exemplar items, as well as between Exemplar and Unstudied items, supports the claim that both perceptual and conceptual information are used in recognition-without-identification of pictures. Remarkably, the behavioral results of the current study suggest that dual routes to recognition (item-specific and gist-based; Marsolek, 1999) are employed even when recognition behavior lacks retrieval awareness. Further work examining both perceptual and conceptual information in other forms of recognition without awareness, like implicit recognition, would need to be conducted to substantiate this suggestion.

The idea that both perceptual and conceptual information contribute to recognition without-identification for pictures is further supported by our electrophysiological data, which showed topographically distinct ERPs related to true and false recognition in the Unidentified trials. While the N300 was observed over occipital areas in relation to true recognition (Studied – Exemplar) during the Unidentified trials, we also observed another negative old/new effect for Exemplar items compared to Unstudied items during the 300–500 ms epoch, but over the right parietal region. This ERP effect corresponded with the behavioral finding of false recognition of Exemplars compared to Unstudied items. The finding of distinct ERP effects for true and false recognition in the current study is again consistent with fuzzy trace theory (Brainerd & Reyna, 2002), which would predict distinct neural activity for true recognition based on item-specific details and false-recognition based on gist information. Previous ERP (Nessler, Mecklinger & Penney, 2001) and neuro imaging studies (Slotnick & Schacter, 2004; Kim & Cabeza, 2007) have also shown distinct neural activity for true recognition of studied items and false recognition of conceptually similar lures. For example, Slotnick and Schacter (2004) used neuro imaging to find that early visual areas were more active for true recognition (i.e., hits) compared to false recognition (i.e., false alarms), but both true and false recognition commonly activated later more anterior multimodal visual areas. Demonstrating a more striking distinction between true and false recognition, Kim and Cabeza (2007) showed that, given high-confidence responses, medial temporal areas showed greater BOLD activity for true recognition than for false recognition, but fronto-parietal areas showed greater BOLD activity for false recognition than for true recognition. Although the right parietal negativity found in relation to the Exemplar items may be mediated by the use of conceptual or gist-based information for recognition, we take caution at endorsing this claim since it is quite different than previously reported ERP activity related to conceptual implicit memory (Voss, Lucas & Paller, 2012). Further research is necessary to determine this link.

4.5 What are the processes behind recognition-without-identification?

Our main findings suggest that recognition-without-identification for pictures is mediated by both perceptual and conceptual information and likely lacks retrieval awareness. Together, these results imply that recognition-without-identification could be based on the use of both perceptual and conceptual priming or fluency. How does the use of perceptual and conceptual fluency eventually lead to recognition-without-identification for pictures? In regards to the other forms of recognition that we discussed, the processing step that implicit recognition and familiarity have in common is that both are based on enhanced fluency of an item. However, implicit recognition and familiarity differ on how fluency is then used for recognition. Implicit recognition may be dependent on making a direct perceptual

comparison of old and new items. In support of this, Voss, Baym and Paller (2008) found implicit recognition effects with a two item forced-choice task but not with a single-item yes/no recognition task. They suggested that the comparison of two items at test was critical for eliciting the differences in fluency between the items, eventually leading participants to choose the more fluent item. However, the current study used a single-item recognition response so a direct perceptual comparison was not possible. How, then, does fluency lead to recognition-without-identification? It is possible that, like familiarity (Jacoby & Whitehouse, 1989; Whittlesea, 1993), recognition-without-identification relies on a late process that attributes fluency to memory. Only a few studies of familiarity have shown ERP activity related to inhibiting the attribution of fluent items to memory by separating fluency from old/new status (Wolk et al., 2004; Kurilla & Gonsalves, 2012). Although the same analysis could not be done in the current study, it remains possible that an attribution process could have taken place during recognition-without-identification. It is difficult to conceptualize how recognition-without-identification is mediated by a process that uses fluency because while fluency describes the relative ease of processing information, recognition-without-identification occurs under conditions that make it too difficult to identify test items. One possibility is that participants did not extract enough information from the test items for full identification on the Unidentified trials, but the relative differences in fluency between the item types were preserved well enough to change responses on the recognition ratings. Since the participants could not identify the items but were still *forced* to make a recognition decision, they may have applied the relative differences in fluency to make their response. That is, the rating scale became less of a measure of recognition and more of a measure of item fluency.

4.6 Conclusions

In conclusion, our results provide support for the claim that recognition-without identification for pictures is related to memory retrieval without awareness. We found that this phenomenon elicited an early negative old/new effect that was very similar in time course and topography as activity related to other forms of recognition without awareness, including implicit recognition (Voss & Paller, 2009) and recognition-without-identification for words (Ryals et al., 2011). Our results also suggest that both perceptual and conceptual information drive recognition-without-identification using distinct neural mechanisms. The contribution of both perceptual and conceptual information to recognition-without-identification imply that pictures can activate multiple routes to recognition, remarkably, even when there is no awareness of memory retrieval.

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Highlights

- Recent theory posits that implicit memory influences explicit recognition decisions
- Picture recognition-without-identification uses perceptual and conceptual information
- ERPs helped examine processes behind picture recognition-without-identification
- Distinct ERPs were found for accurate recognition with and without awareness

Figure 1. Tables of BOLDAR scores indexing the similarity between pairs of items. The items arranged along the vertical axis are compared to items arranged along the horizontal axis and BOLDAR values are indicated by color. Tables A and B provide examples of the BOLDAR analysis on our picture set. These tables are arranged so that within-category comparison scores lie along the diagonal; every other value is an across-category score. Table A depicts a random selection of 6 items from the experiment compared to their exemplars. Some exemplar pairs, like the grasshoppers, are highly dissimilar, while others like the axes, are highly similar. Table B depicts the same analysis applied to 6 items compared to the same 6 items. The values along the diagonal of the table all equal 1, indicating that they are identical. Table C

depicts the results of the BOLAR analysis on all 66 categorical exemplar pairs. Selected items are depicted on each axis (item 10, item 20, etc.). As shown on the bottom table, the mean similarity scores of within-category comparisons (on-diagonal) are not significantly different than the mean similarity scores of across-category comparisons (off-diagonal).

Figure 2.

A schematic of the Study and Test phases of the behavior procedure. The callout depicts the types of items that could appear during the test, including the Studied item, Exemplar item, and an Unstudied item.

Figure 3.

(A) Identification performance across all three test conditions. (B) The average rating for unidentified items. (C) The average rating for identified items. * $p < 0.05$, ** $p < 0.001$

Figure 4.

Maps of scalp regions of interest displaying significant memory effects for the Identified trials. Regions with positive old/new effects are colored in red and regions with negative old/new effect effects are colored in blue.

Figure 5.

Scalp regions of interest displaying significant memory effects for Unidentified trials. Regions with positive old/new effects are colored in red and regions with negative old/new effect effects are colored in blue.

Figure 6. Scalp topographies for the critical contrasts. Each topography represents averaged ERP activity from the labeled time-point forward.

Figure 7.

ERP waveforms for each topographic region of interest. Gray regions indicate epochs when significant old/new effects were found; the specific effects found in each epoch are detailed in Figures 4 and 5. An example of how the scalp regions were divided appears in the center.