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Recognition Without Identification for Words, Pseudowords and Nonwords

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Abstract

Three experiments examined whether the representations underlying recognition memory familiarity can be episodic in nature. Recognition without identification (Cleary & Greene, 2000; Peynircioğlu, 1990) was used to isolate familiarity processes. In order to test whether the representations underlying familiarity can be episodic, participants were exposed to stimuli that should not have pre-experimental representations, pseudowords and nonwords. The first two studies found evidence of recognition without identification for pseudowords and nonwords, a result that is inconsistent with views proposing familiarity only arises from existing representations. The third study found evidence that recognition without identification for words, pseudowords, and nonwords is stronger when study and test modality match. These results are interpreted within the framework of global-matching views of recognition memory, which claim that familiarity arises from the matching of test items to episodic representations in memory.

There is substantial agreement that a familiarity process contributes to recognition memory (Atkinson & Juola, 1973; Hintzman, 1988; Mandler, 1980; Reder, Nhouyvangsivong, Schunn, Ayers, Angstadt, & Hikari, 2000; Shiffrin & Steyvers, 1997). Despite this agreement, models differ regarding the nature of the representations underlying familiarity. Some models suggest that familiarity processes result from increasing the activation of existing representations (Atkinson & Juola, 1973; Reder, et al., 2000), while other models suggest that the representations underlying familiarity contain episodic details (e.g., Hintzman, 1988; Shiffrin & Steyvers, 1997).

One example of a model that claims existing representations underlie familiarity is the *Source of Activation Confusion* model (SAC; Reder, et al., 2000). According to SAC, experiencing an item during encoding activates a *concept node*, which represents the general exposure history of an item, such as its frequency and recency of exposure. In addition, encoding involves the formation of an *episode node*, which binds the item's concept node to features of encoding context. Retrieval of an episode node produces recollection of a test item's occurrence on a study list, while assessment of the activation level of a concept node underlies familiarity, with higher levels of representation activation corresponding to greater familiarity. Thus, items that have been experienced recently, such as the words during the study portion of an experiment,

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will generally have concept nodes that are more active than items that were not experienced recently, and will therefore be more familiar. Critical for present purposes, this characterization of familiarity suggests that it is necessary for an item to have a pre-experimental representation (i.e., concept node) in order for that item to be recognized on the basis of familiarity. For the sake of expositional expedience, we refer to this general view as *existing representation theories* below.

In contrast, global-matching models, such as MINERVA2 (Hintzman, 1988) and REM (Shiffrin & Steyvers, 1997), assume that episodic representations can produce familiarity. In both of these models, items in memory are composed of vectors of features (indexed by 1, 0, -1 in MINERVA2 and positive integers in REM). Encoding is a process whereby some of an item's features are sampled and encoded in to a memory vector. At retrieval, test probes are matched to all of the traces in memory, which results in a value representing how well that test probe matches the contents of memory, and therefore the item's familiarity. Thus, the better a test probe matches the contents of memory, the greater the test item's familiarity and the greater the likelihood a person will judge that test item to have been encountered during the study episode. The critical dimension of global-matching models for present purposes is that test probes are matched to memory traces that were acquired during a specific experience, which in turn suggests that familiarity is based upon representations that are episodic in nature. We refer to this general view as *episodic representation theories* below.

The present research tested existing representation and episodic representation theories of familiarity by evaluating if familiarity-based memory representations can mediate learning of stimuli that had not been encountered prior to our experiments – nonwords (e.g., *pcgq*). Existing representation theories generally claim that familiarity-based recognition of nonwords should not be possible, because nonwords have not been experienced previously, which in turn means they do not have a representation in memory that can be primed the first time they are encountered in an experiment. Episodic representation theories, on the other hand, generally claim that familiarity-based recognition of nonwords should occur. For example, in global-matching models, the memory traces that underlie familiarity were acquired during a specific episode. Thus, the first time a nonword is encountered, a memory trace of that experience will be stored, and that trace will later contribute to a test item's familiarity.

In general, studies using measurement techniques to separate recollection- and familiarity-based recognition judgments (e.g., remember-know judgments; Tulving, 1985) have found that familiarity-based processing can underlie memory for nonwords (Gardiner & Java, 1990) and novel shapes (Yonelinas & Jacoby, 1995). Thus, the existing data favor episodic representation theories of familiarity processes over existing representation theories, because nonwords and novel shapes are unlikely to have a pre-experimental representation that can be activated when they are studied. However, measurement techniques that separate recollection from familiarity have been criticized on various grounds, ranging from whether remember-know judgments truly reflect the memorial states of recollection and familiarity (Donaldson, 1996; Dunn, 2004; Hirshman & Master, 1997), to whether techniques that separate recollection from familiarity should assume the two memory processes are independent or correlated (Curran & Hintzman, 1997). The present studies seek to further examine this question with a phenomenon that has been purported to be driven by familiarity-based representations, *recognition without identification* (Cleary & Greene, 2001; 2005; Peynircioğlu, 1990). Studying whether recognition without identification occurs for stimuli that do not have pre-experimental representations (e.g., nonwords) provides a strong test of whether the representations underlying familiarity can mediate learning of novel stimuli, and therefore also strongly challenges episodic and existing representation theories of familiarity. Further, examining whether or not recognition without identification occurs for novel stimuli potentially provides converging evidence for the conclusions of studies using measurement techniques designed to

separate recollection and familiarity-based recognition (Gardiner & Java, 1990; Yonelinas & Jacoby, 1995).

In the paradigm used to study recognition without identification, participants are first presented with a list of items to study. Following the study list, participants are given a recognition memory test where they are presented with both studied and unstudied items. Further, the test items are presented such that they are difficult to identify. For example, a participant may be asked to identify each test item in a perceptual identification task. Then, regardless of whether or not the participant was able to identify the item that was presented on the perceptual identification trial, (s)he is asked to provide a rating of the likelihood the item that was presented on the identification trial was also shown during the study episode (e.g., on a scale from 1 = *definitely not presented on the study list* to 9 = *definitely presented on the study list*). Performance on identification trials creates two classes of items: items that participants identified and items that they were unable to identify. Not surprisingly, participants provide higher mean ratings to studied items than unstudied items for stimuli that they were able to identify prior to judging the items' studied status. However, ample evidence also exists that the mean rating to studied items is higher than the mean rating to unstudied items for stimuli participants were unable to identify, a result referred to as *recognition without identification* (e.g., Cleary, 2005; Cleary & Greene, 2000; 2001; 2005; Peynircioglu, 1990).

Substantial empirical evidence suggests that recognition without identification is mediated by familiarity-based processes (Cleary, 2004; 2005; Cleary & Greene, 2001; 2005). Two empirical findings provide particularly compelling evidence. First, recognition without identification occurs in tasks that receive an extensive contribution from familiarity-based processes (e.g., item recognition or frequency judgments), but is less pronounced in recognition tasks when recollection contributes extensively (e.g., associative recognition or list discrimination; Cleary & Greene, 2001; 2005). Second, the slope of the z -transformed ROC curve for unidentified test items is approximately 1.0 (Cleary, 2004; 2005). This result is important because a unit slope z -ROC is consistent with performance being mediated by a simple signal-detection process where familiarity for old and new items have the same variance (Swets, 1986), precisely the kind of familiarity process proposed by a common dual-process model of recognition memory (Yonelinas, 1997). In contrast, recognition memory studies typically find z -ROC slopes in the range of 0.7 to 0.8 (e.g., Ratcliff, Sheu, & Gronlund, 1992). Within the framework of Yonelinas's dual-process explanation of ROC curves, this result indicates that performance results from the combination of recollection and familiarity processes. Thus, the z -ROC slope of 1.0 found for recognition without identification is consistent with performance being mediated by familiarity without the contribution of recollection (Cleary, 2004; 2005).

The predominant explanation of recognition without identification uses principles implemented in global-matching models of recognition memory (Cleary & Greene, 2001), such as MINERVA2 (Hintzman, 1988) and REM (Shiffrin & Steyvers, 1997). This explanation suggests that the basis for recognition without identification is partial matching of test items to representations in memory. In particular, the global-matching approach suggests that when an item is not identified accurately, participants nevertheless are able to discern some of the letters in the item, as well as the position of those letters within the test item. Participants then use the letter and letter position information to probe their memory for evidence that the item that was presented on the identification trial was studied. Items that were studied will tend to produce partial probes that match a trace in memory slightly better than items that were not studied. This will, in turn, lead participants to judge unidentified items that were studied as more likely to have occurred on the study list than unidentified items that were not studied. Thus, the memory processes that have been proposed to underlie many instances of recognition without identification are borrowed from episodic representation theories of familiarity (Cleary

& Greene, 2001; Cleary, 2004; see Cleary, 2006; Cleary & Specker, 2007 for non-episodic accounts).

Despite the use of an episodically-based model to explain many instances of recognition without identification, all of the research studying recognition without identification to date has utilized words (Cleary, 2004) or objects (Cleary, Langley, & Seiler, 2004) that are commonly experienced in everyday life. Thus, it is possible that recognition without identification only occurs when participants possess an existing representation that can be activated during encoding and retrieved (in part) at test. Consequently, it is unclear whether or not the representations underlying familiarity processes, as measured by recognition without identification, can support learning of materials that do not possess pre-experimental representations.

In the present studies, participants were exposed to three types of stimuli: words, pseudowords and nonwords (Stark & McClelland, 2000). Examining recognition without identification for words provides a basic replication of many prior studies documenting the existence of recognition without identification (e.g., Cleary, 2004). Pseudowords are items that maintain the basic orthographic regularities of the English language (e.g., *horn*), but pseudoword orthography does not correspond to any meaningful referent in the language (Stark & McClelland, 2000). Thus, they are unlikely to have been experienced by participants prior to an experiment. However, implicit memory studies suggest that pseudoword priming can be mediated by their sublexical components, such as the phonemes and morphemes that make up pseudowords (Dorfman, 1994). Thus, observing recognition without identification for pseudowords will demonstrate that existing *lexical* representations are not needed to mediate recognition without identification, but will leave open the possibility that recognition without identification can be mediated by existing *sub-lexical* representations. Finally, nonwords do not possess any of the orthographic regularities of the English language (e.g., *pcgq*); therefore, it is unlikely that recognition without identification for nonwords can be mediated by pre-experimental representations of a whole nonword (lexical representations) or of groupings of letters, such as bigrams and trigrams, that make up a nonword (sublexical representations). Thus, observing recognition without identification for nonwords will provide evidence that recognition without identification can occur in the absence of an existing representation in memory.

Given this basic design, episodic representation theories of familiarity predict that recognition without identification should be observed for words, pseudowords, and nonwords (Hintzman, 1988; Shiffrin & Steyvers, 1997). In essence, proposing that familiarity is supported by episodic representations suggests that a single exposure is sufficient to produce familiarity-based recognition of a stimulus, leading to enhanced ratings for studied items compared to unstudied items. Thus, no pre-experimental representation is required to produce familiarity, allowing items that are experienced for the first time in one's life to be recognized only with familiarity. In contrast, existing representation theories of familiarity predict that recognition without identification should occur for words, and perhaps for pseudowords (provided the model proposes a role for sublexical representations in recognition), but not for nonwords (Atkinson & Juola, 1974; Reder, et al., 2000). This prediction is derived from the property of existing representation theories that familiarity is the result of increasing the activation level of pre-experimental representations in a concept network.

In addition to examining whether recognition without identification occurs for all three stimulus types, the general claim that recognition without identification is mediated by familiarity processes can be evaluated by assessing the slope of the *z*-ROC for unidentified items. Prior research has demonstrated that the *z*-ROC for unidentified words shows a slope of 1.0 (Cleary, 2004; 2005). This result is consistent with the theory that recognition without

identification for words is mediated by an equal-variance signal-detection process (Swets, 1986). In the context of recognition memory theory, a z -ROC slope of 1.0 has been taken to indicate performance is mediated by familiarity in the absence of recollection (Yonelinas, 1997). We will test the generality of these results with words by examining z -ROCs for unidentified pseudowords and nonwords. Thus, if pseudoword and nonword recognition without identification are mediated by familiarity in the absence of recollection, they should also show z -ROC slopes of approximately 1.0.

Experiments 1 and 2

In both Experiments 1 and 2, participants were exposed to one study list for each of three stimulus types: Words, nonwords, and pseudowords. Each study list was followed by a test list composed of the studied items and a comparable set of unstudied items of the same stimulus type. The only difference across the two experiments was the word stimuli that were used. In Experiment 1, the word stimuli were taken from the same source as the pseudowords and nonwords, Stark and McClelland (2000). In Experiment 2, low-frequency words between four and eight letters in length from Kucera and Francis (1967) were used. The reason for this procedural difference is that in Experiment 1, recognition without identification was not found for the word stimuli. The lack of recognition without identification in Experiment 1 may have been an artifact of presenting the word stimuli in the perceptual identification task at a rate that was too rapid, causing identification of words to be all-or-none. Thus, participants may have been unable to perceive *any* orthographic information from the words in Experiment 1 when they were unable to identify a stimulus on the perceptual identification trials, leading them to have no information with which to cue familiarity processes. Experiment 2 remedied this potential problem by using words that would be slightly harder to identify in a perceptual identification task (low frequency items) and increasing the duration of the perceptual identification trials. Given the similarity between the two experiments, we present their methodology and results together for ease of exposition.

Method

Participants

Participants were 72 students from Middlebury College who participated as part of an Introduction to Psychology research appreciation requirement. Thirty-six students participated in each experiment.

Materials

The stimuli for Experiment 1 were 60 words, 60 pseudowords, and 60 nonwords taken from Stark and McClelland (2000), Experiment 3. These stimuli were chosen because Stark and McClelland ensured that lexical similarity within a stimulus type was comparable for words, pseudowords and nonwords. Thus, their stimuli were constructed to ensure that words, pseudowords and nonwords were equally likely to share two or more letters in the same position with another item in their stimulus type. This is important because it is possible for stimuli within a test list to activate the representations of similar stimuli (Feustel, Shiffrin, & Salasoo, 1983), which could lead to a greater likelihood of observing recognition without identification for item classes that tend to have greater inter-item lexical similarity. In the case of the stimuli used in the current studies, words tend to have greater within-class lexical similarity than pseudowords, which in turn tend to have greater within-class lexical similarity than nonwords (Stark & McClelland, 2000). Thus, intra-class similarity is important to control in order for words, pseudowords, and nonwords to have an equal opportunity to show recognition without identification.

Stark and McClelland constructed their stimuli such that all were four letters in length. Words were sampled from the MRC database (Coltheart, 1981), had word frequencies between 10 and 200 (Kucera & Francis, 1967), and scored a maximum of 500 on the concreteness and imageability scales. Further, word stimuli were excluded from their corpus if they began with a vowel, had double letters, or contained the consonants *w*, *x*, *k*, *q*, *j*, or *g*. Pseudowords were generated by Stark and McClelland by taking two of the words and switching the first letters to generate a pseudoword (e.g., *holy* and *norm* had their first letters switched, creating the pseudowords *horn* and *noly*). Nonwords were constructed by using the words and replacing the vowels *a*, *e*, *i*, *o*, *u*, and *y* with *w*, *x*, *k*, *q*, *j*, and *g*, respectively, and re-ordering the letters of the word, such that they were spelled 3-1-4-2 (e.g., *holy* would become *hqlg* from the vowel replacement, and then *lhgq* from re-ordering the letters). Finally, Stark and McClelland (2000) ensured that no two items within a stimulus type shared three letters in the same position. For the construction of the word stimuli in Experiment 2, the words from Stark and McClelland (2000) were replaced with 60 words chosen from Kucera and Francis (1967) that varied in word length from four to eight letters and had word frequencies between one and four occurrences per million.

Each of the three types of stimuli was divided into two sets for old-new counterbalancing purposes, with 30 stimuli of each type of item serving as studied items for half of the participants and the other 30 stimuli of each type of item serving as studied items for the other half of the participants. The 30 stimuli from each type of item that were not studied by a given participant served as unstudied control items, which provided a measure of participants' baseline ability to identify items on the perceptual identification task, as well as participants' baseline judgments of the likelihood that an item was presented on the study list.

Procedure

Each experimental session consisted of three blocks of study and test trials in which all aspects of the procedure were the same, with one exception to be noted below. During each study list, participants were presented with 30 study items. Study items were presented sequentially on a computer screen for 3400 msec each, with a 100 msec ISI. Participants were instructed to read each stimulus one letter at a time, and were asked to not pronounce the stimulus as a whole. The intent of this instruction was to equate participants' initial stimulus processing of nonwords (which are not pronounceable) with that of pseudowords and words. Following the presentation of each study list, participants were given a memory test. Each test list consisted of the 30 studied items from the immediately preceding study list and 30 unstudied items of the same stimulus type, presented randomly intermixed. On each trial, participants were presented with a prompt ("Get Ready!") and fixation cross ("+") for 500 msec. The fixation prompt was then replaced by the test stimulus for a brief period of time (16 msec for words in Experiment 1, 33 msec for words in Experiment 2, 50 msec for pseudowords and 67 msec for nonwords),¹ which was in turn replaced by a backward pattern mask consisting of a row of dollar signs (\$\$\$\$\$\$ \$\$\$\$\$\$). Participants were instructed that their task was to do their best to identify each stimulus following its presentation. Participants were asked to identify each stimulus by typing it in a response box that appeared one second after the onset of the backward pattern mask. Participants were instructed to guess if they were unsure of the stimulus that was flashed on the computer screen. Following the typing of each response, participants were asked to provide a judgment of how likely it was that the item that was flashed on that trial was presented on

¹The purpose of these different perceptual identification presentation durations was because pilot testing suggested that these durations would produce approximately equivalent baseline performance (approximately 25% correct identification) for each stimulus type in Experiment 1. The longer presentation duration for word stimuli in Experiment 2 was chosen because the words were of low frequency and varied in length, making them harder to identify. However, pilot testing of the appropriate duration of presentation for words in Experiment 2 was not carried out, which is why baseline identification rates for words were considerably higher for words than pseudowords and nonwords.

the study list. Participants were asked to provide their responses on a scale from 1 (certain the item *was not* presented on the study list) to 9 (certain the item *was* presented on the study list). Participants were further instructed that even if they were unable to identify the stimulus that was presented on the trial, they should make a judgment about how likely it was that the item was presented on the study list. Finally, when participants were unable to correctly identify an item prior to making their recognition judgment, they were given a second opportunity to guess what the flashed stimulus was after making a recognition judgment. This second guess was used to ensure that participants did not generate a correct identification of the stimulus on that trial after providing their first response, but before they judged the likelihood the stimulus was shown on the study list.

Following the presentation of the first study and test list, participants were given a second study and test list that was identical, with the exception of the stimuli that were presented during the study and test lists, as well as the presentation duration of stimuli on the perceptual identification trials. The order of presentation of each stimulus type (first, second, and third study-test list) was counterbalanced such that each stimulus type occurred equally often in the first, second, and third study-test list.

Results

Three basic analyses are reported. First, analyses of the probability of identification for each stimulus type are presented. These analyses are intended to illustrate that typical repetition priming results were observed in the perceptual identification task (e.g., Gabrieli, Fleischman, Keane, Reminger & Morrell, 1995). Second, analyses of the confidence ratings for items that were and were not identified in the perceptual identification task are presented. These analyses will establish whether recognition memory discrimination occurred when stimuli were identifiable, and, critically, whether recognition without identification occurred for each stimulus type. Third, we examined the z -ROCs for the unidentified test stimuli for each stimulus type. These analyses will establish if the z -ROCs for unidentified words, pseudowords, and nonwords showed characteristics that were consistent with performance being mediated by familiarity-based processing. Specifically, we examined the slopes of the z -ROCs, and tested the hypothesis that they were approximately 1.0. All statistical hypothesis tests were conducted with $\alpha = .05$.

Repetition Priming Analyses

Table 1 presents the probability of identification for studied and unstudied items separately for each stimulus type in Experiments 1 and 2. All three stimulus types showed reliable repetition priming in both experiments (smallest $t(35) = 2.25$ for nonwords in Experiment 1).

Confidence Ratings for Identified and Unidentified Items

Table 2 presents the mean ratings for identified and unidentified items for each stimulus type in Experiments 1 and 2 as a function of whether the item was studied (old) or not studied (new). For *identified* items, the mean ratings for studied items was higher than the mean rating for unstudied items for all stimulus types in both experiments (smallest $t(35) = 2.03$ for nonwords in Experiment 1). For *unidentified* items, the mean rating for old items was higher than the mean rating for new items in five of the six comparisons across the two experiments. In Experiment 1, the ratings for old pseudowords and nonwords were reliably higher than the ratings for new pseudowords and nonwords, respectively ($t(35) = 3.09$ for pseudowords and $t(35) = 2.39$ for nonwords). However, the ratings for old words were not reliably different than the ratings for new words, $t(35) = 0.10$. In Experiment 2, the ratings for old items were reliably higher than the ratings for new items for all three item types (smallest $t(35) = 2.42$ for words). Thus, in Experiment 2, recognition without identification was found for all three types of

stimuli, while in Experiment 1, recognition without identification was found for pseudowords and nonwords, but not words.

z-ROC Analyses

Finally, we examined the z -ROCs for unidentified words, pseudowords and nonwords in an effort to establish that recognition without identification occurred due to a simple signal detection process. To this end, we computed z -ROCs for each subject in Experiments 1 and 2 for each stimulus type. As a consequence of how they distributed confidence judgments, computation of individual z -ROCs was not possible for 4 participants' responses to nonwords in Experiment 1, 2 participants' responses to nonwords in Experiment 2, 13 participants' responses to pseudowords in Experiment 1, 2 participants' responses to pseudowords in Experiment 2, 7 participants' responses to words in Experiment 1, and 16 participants' responses to words in Experiment 2. Mean z -ROC slopes and intercepts for words, pseudowords, and nonwords are presented in Table 3.

The intercept of the z -ROC was above zero for all conditions with the exception of words in Experiment 1. Given that words in Experiment 1 failed to show evidence of recognition without identification, this was the expected result from z -ROC intercept analyses. For the remaining item types, the above-zero intercepts of the z -ROCs indicate that participants were able to discriminate old items from new items even when they were unable to identify them, consistent with the conclusions from analyses of mean judgments for unidentified old and new items. However, the z -ROC intercept was not *reliably* greater than zero for pseudowords in Experiment 1 ($t(22) = 1.99, p < .06$), pseudowords in Experiment 2 ($t(33) = 1.64, p < .15$), words in Experiment 1 ($t(26) = -1.32$), or words in Experiment 2 ($t(19) = 1.62, p < .15$). The intercept of the z -ROC was reliably greater than zero for nonwords in Experiment 1 ($t(31) = 2.08$) and Experiment 2 ($t(33) = 2.21$). The fact that not all intercepts were reliably above zero raises concerns about any interpretation of z -ROC slopes, because the slope of the z -ROC will naturally tend toward 1.0 as performance moves toward chance (i.e., a z -ROC intercept of 0.0). Therefore, we also analyzed two subsets of the data for each stimulus type: participants who showed z -ROC intercepts greater than 0.0, and participants who showed z -ROC intercepts greater than .10 (Hirshman & Hostetter, 2000). Restricting data analysis to these subsets naturally induces a z -ROC intercept greater than zero, both in terms of condition means and statistical significance. Thus, concerns about interpretation of z -ROC slopes near 1.0 are mitigated, because the tendency for slopes to fall along the major diagonal is lessened as the intercept diverges from 0.0. The mean slopes and intercepts for these restricted data sets are presented in the lower two panels of Table 3. In all six cases, the slope of the z -ROC was close to 1.0, and none significantly differed from 1.0, despite mean z -ROC intercepts as high as 0.50 in the pseudoword and nonword conditions of Experiment 1. Thus, the z -ROC analyses support the interpretation that recognition without identification for words (Cleary, 2004; 2005 and the present Experiments 1 and 2), pseudowords, and nonwords is mediated by familiarity-based representations. Further, these analyses extend the domain of recognition memory familiarity, as measured by recognition without identification, to pseudowords and nonwords.

Discussion

Experiments 1 and 2 found evidence that recognition without identification occurred for both pseudowords and nonwords. These results extend existing demonstrations of recognition without identification for words (Cleary & Greene, 2000, 2001) and pictures (Cleary, et al., 2004) to the domain of stimuli without pre-experimental representations. Further, these results are consistent with the conclusions from prior studies that used remember-know judgments to separate the contribution of recollection- and familiarity-based processes to recognition of novel stimuli (e.g., Gardiner & Java, 1990; Yonelinas & Jacoby, 1995). Thus, the combination

of previous studies using the remember-know paradigm and the present finding of recognition without identification for pseudowords and nonwords strongly suggest that the memory representations underlying familiarity processes can mediate learning of novel information.

One final dimension of Experiment 1 and 2's results merits comment. Prior research has shown that pseudowords tend to produce higher hits and false alarms relative to words (e.g., Greene, 2004). This tendency was not observed in Experiments 1 and 2, where one might expect to observe higher confidence ratings for pseudowords than words (see Table 2). While it is difficult to be conclusive regarding why confidence ratings were not higher for pseudowords than words, one important dimension of Experiments 1 and 2 was that the stimuli were rigorously controlled for inter-item lexical similarity (Stark & McClelland, 2000). Recent evidence has suggested that the reason pseudowords show higher hits and false alarms than words is that pseudowords are more familiar than words, possibly because pseudowords have greater similarity to other items in memory relative to words (Greene, 2004). Thus, it is possible that equating words and pseudowords on lexical similarity equated one of the primary stimulus dimensions that lead pseudowords to be more familiar than words, which in turn eliminated differences between words and pseudowords in terms of confidence ratings.

The occurrence of recognition without identification for stimuli that lack pre-experimental representations is consistent with episodic representation theories of familiarity (Hintzman, 1988; Shiffrin & Steyvers, 1997; Yonelinas, 1997), and is inconsistent with existing representation theories of familiarity (Atkinson & Juola, 1973; Reder, et al., 2000). It may be possible, however, to modify existing representation theories to account for these results. Reder, Angstadt, Cary, Erickson, & Ayers (2002) described a process by which familiarity-based representations for pseudowords could be formed via repeated exposure within the framework of the SAC model of memory. SAC proposes that upon exposure to a pseudoword, a person will attempt to create a single representation of that experience by binding together representations of the simple units that make up that pseudoword. For example, when they encounter the pseudoword *gret*, a person will form a representation of that experience that was associated to their existing representations for *gr* and *et*. Over the course of repeated exposure to *gret*, participants will form a representation for *gret* that is strong enough to function as a concept independent of its association to *gr* and *et*. Importantly, this account can be extended to explain the formation of unitized representations for nonwords by positing that the experience of a nonword such as *pcgq* is initially represented as the association among letter representations for *p*, *c*, *g*, and *q*. Then, over repeated exposure to *pcgq*, one will construct a concept for that nonword that could function independent of its association to the individual letters used to form that concept initially.

Important for understanding this theory's explanation of the results of Experiments 1 and 2 is that initially, familiarity-based judgments are based upon a very weak, but existent, representation that was formed during the first exposure to the stimulus. When a memory probe for an unidentified test item is constructed, the search process will activate individual letters and/or sublexical representations in an effort to search for a representation that is both active and represents an episodic experience that closely matches the test probe. Thus, it is possible for an existing representation theory of familiarity, SAC, to account for recognition without identification for pseudowords and nonwords by positing the formation of an episodic representation that binds together either sub-lexical components of an item (pseudowords) or individual letters (nonwords). Experiment 3 will provide a test of this theory, as well as an additional test of episodic representation theories of familiarity, by manipulating the match between study and test modality. To anticipate, manipulating modality match between study and test evaluates whether the representations mediating familiarity contain information specific to an experience, such as perceptual information that was encoded as part of an experience. Thus, to the extent the representations underlying familiarity for words,

pseudowords, and nonwords are episodic, one would expect matching modality from study to test to increase familiarity, and consequently, recognition without identification, relative to a condition where modality does not match from study to test.

Experiment 3

In this experiment, we examined the nature of the representations underlying recognition without identification for words, pseudowords, and nonwords by manipulating the match between study and test modality. The extent to which recognition without identification is stronger for the match than the mismatch condition will provide evidence that the representations underlying performance contain perceptual information. Similarly, the extent to which recognition without identification is present in the modality mismatch condition will provide evidence that the representations underlying performance are not modality-dependent, and instead represent abstract information about an event. Thus, Experiment 3 provides a test of the empirical generality of recognition without identification for pseudowords and nonwords, while also examining the extent to which familiarity processes are mediated by perceptual and non-perceptual representations.

Previous research has shown that recognition without identification occurs when the modality between study and test does not match (Cleary & Greene, 2000), and can occur even when a test item was not directly experienced, but its associates were studied (Cleary & Greene, 2004). Both of these results demonstrate that recognition without identification occurs in the absence of an exact perceptual match between encoding and retrieval, suggesting that abstract (i.e., non-perceptual) representations can underlie familiarity processes. However, it is not known whether an exact perceptual match between encoding and retrieval enhances recognition without identification. While Cleary and Greene (2000) showed that recognition without identification occurred when study was auditory and testing was visual, they did not directly compare experimental conditions where modality matched from study to test and did not match from study to test. Nonetheless, Cleary and Greene's (2000) data are suggestive of a modality match effect. There were two pairs of experiments that were identical with the exception of the match between study and test modality (Experiments 1 and 2D; Experiments 3A and 3B, where modality matched between study and test in the former experiment of each pair and mismatched between study and test in the latter experiment of each pair). In both cases, effect size measures were larger when study and test modality matched ($d = 1.49$ and $d = 2.49$ in Experiments 1 and 3A, respectively) than when they did not match ($d = 0.92$ and $d = 1.40$ in Experiments 2D and 3B, respectively). Thus, existing evidence suggests that a modality match effect occurs for words. Experiment 3 will provide a direct test of the modality match effect for words. Additionally, Experiment 3 will extend Cleary and Greene's (2000) work to study modality-match effects for nonwords and pseudowords.

In addition to extending prior empirical results for recognition without identification, manipulating modality match tests episodic and existing representation theories of familiarity processes. In general, episodic representation theories suggest that a modality match effect should occur for words, pseudowords, and nonwords. This prediction can be understood by considering that the basic property of episodic representation theories is that the representations underlying familiarity are composed of sets of features representing an experience. Thus, because the representations that underlie familiarity represent a specific experience, they should contain information about the details of that experience, such as the modality in which a test item was studied. Existing representation theories, on the other hand, would expect no modality match effect to occur. This prediction can be understood by considering that existing representations do not represent a specific encounter with a stimulus, and instead are based upon incrementing the activation value of a representation when an item is experienced. Thus,

there is no provision within existing representation theories for representing the modality of an experience, and no expectation of a modality match effect.

Experiment 3 also provides a test of Reder, et al.'s (2002) explanation of how existing representation theories can explain familiarity for pseudowords and nonwords. This theory posits that nonword recognition without identification initially is mediated by a very weak episodic representation that binds together the letters used to form a nonword. Pseudoword recognition without identification could be mediated by one of two mechanisms: activation of existing sublexical representations or the formation of a very weak episodic representation, as is the case for nonwords. Finally, word recognition without identification should be mediated only by existing representations. As noted above, to the extent that familiarity is mediated by episodic representations, one would expect a modality match effect to occur. However, in cases where existing representations are proposed to mediate familiarity, one would not expect recognition without identification to occur. Thus, Reder, et al.'s (2002) theory proposes that a modality match effect should occur for nonwords, and should not occur for words. The theory can accommodate either the presence or absence of a modality match effect for pseudowords, depending on whether familiarity is mediated by a new episodic representation of an entire pseudoword (leading to the prediction of a modality match effect) or existing sublexical representations (leading to the prediction of no modality match effect).

Method

Participants

Participants were 90 students at Middlebury College who participated as part of an Introduction to Psychology course requirement or in exchange for \$10 payment.

Materials

The visual stimuli and visual study task were the same as those used for Experiment 2. Each stimulus was recorded as a digital audio file of a female reading each letter of a stimulus one at a time from left to right. This form of auditory presentation was used for two purposes. First, it allowed us to present each stimulus aurally while ensuring participants' perception of the stimuli to be accurate. This was particularly important for presenting nonwords and pseudowords aurally. Second, it was the closest aural analog of the visual study task participants were given (reading each stimulus one letter at a time, but not pronouncing the stimulus as a whole). The stimuli within each type of item (words, pseudowords, nonwords) were divided into three sets of 20 for counterbalancing purposes. Each set of 20 items served equally often as an aurally presented study item, a visually presented study item, and a nonstudied test item across participants.

Procedure

The procedure of Experiment 3 was identical to that of Experiment 2 with six exceptions. First, 40 items were presented during study (20 aurally and 20 visually). Second, when an auditory item was presented during the study list, the computer screen was entirely white. Third, auditory and visual study items were randomly intermixed. Fourth, study items were presented for 5500 msec rather than 3400 msec in order to allow for the letters in each auditory file to be clearly enunciated. Fifth, a black screen was presented for 250 msec between each stimulus presentation. This procedural dimension was used to signal the boundary between stimuli, which was particularly important when two auditory stimuli were presented in succession. Sixth, the perceptual identification task presentation times were 33 msec for words, 50 msec for pseudowords, and 83 msec for nonwords. The nonword identification duration was increased in an effort to boost nonword perceptual identification rates, because pilot testing suggested pseudowords and words showed higher identification rates in Experiment 3 than

Experiments 1 and 2. The change in identification rates for pseudowords and words presumably reflected the increased study time (5500 msec) in this experiment compared to the first two (3400 msec).

Results

The same three analyses that were reported for Experiments 1 and 2 were conducted on the data from Experiment 3.

Repetition Priming Analyses

The proportion correct identification for each type of stimulus is presented in Table 4. Identification rates were higher for visually and aurally-presented words than new words (both $t(89) > 6.92$) as well as visually and aurally-presented pseudowords than new pseudowords (both $t(89) > 4.48$), but only visually-presented nonwords were identified more often than new nonwords ($t(89) = 4.51$; $t(89) = 0.29$ for aurally-presented nonwords). Additional paired comparisons indicated that matching modality from study to test improved identification for pseudowords ($t(89) = 6.72$) and nonwords ($t(89) = 4.26$), but not words ($t(89) = 1.30$, $p < .20$). The lack of a modality match effect for word identification may simply reflect the fact that identification rates for words were overall very high ($M > .80$ in both the visual and auditory study conditions).

Confidence Ratings for Identified and Unidentified Items

The mean ratings for identified and unidentified words, pseudowords, and nonwords are presented in Table 5. For *identified* items, there was a difference among the study conditions' ratings for all three types of stimuli (smallest $F(2,178) = 31.29$, $MSE = 0.94$ for nonwords). Individual paired comparisons showed that ratings were higher for visually- ($F(1,89) = 58.66$, $MSE = 0.48$) and aurally-presented nonwords ($F(1,89) = 6.95$, $MSE = 0.41$) than new nonwords, visually- ($F(1,89) = 253.62$, $MSE = 0.64$) and aurally-presented pseudowords ($F(1,89) = 127.06$, $MSE = 0.63$) than new pseudowords, and visually- ($F(1,89) = 210.87$, $MSE = 1.53$) and aurally-presented words ($F(1,89) = 527.22$, $MSE = 1.38$) than new words. Further, there was a modality match effect for both nonwords ($F(1,89) = 25.28$, $MSE = 0.52$) and pseudowords ($F(1,89) = 53.50$, $MSE = 0.28$). However, the opposite pattern emerged for identified words, such that confidence ratings for identified words were higher when they were studied aurally than when they were studied visually ($F(1,89) = 101.59$, $MSE = 0.79$). Thus, for all three types of stimuli, recognition confidence was higher for items studied aurally and visually than for unstudied items when the test stimulus was identified prior to making recognition judgments. Further, both nonwords and pseudowords showed a modality-match effect, while words showed a modality-match disadvantage.

For analyses of *unidentified* items, it was necessary to utilize a statistical technique to account for missing data due to high identification rates in some cells of the design, particularly those for words. Identification rates were 1.0 for 65 of the 810 possible data points in this experiment (9 cells per participant $\times$ 90 participants). When identification rates of test items were 1.0, the participant did not produce any judgments of unidentified items. These 65 missing data points were distributed across 34 participants. Thus, simply eliminating subjects who did not produce at least one observation in every cell would have eliminated a substantial number of participants from the analyses of each item type. We used multiple imputation (Rubin, 1987) as a method to complete the cells where data were missing in order to avoid the potential bias introduced by listwise deletion (see Schafer & Graham, 2002). The desirable statistical properties of multiple imputation relative to other methods are well established (see Allison, 2001; Little & Rubin, 2002).

In short, multiple imputation can be thought of as an elaboration of mean imputation, where missing values for a given variable are simply replaced by the mean (or a conditional mean) of that variable. In that the mean can be viewed as a model for the missing values of a variable, multiple imputation expands the model to preserve the variability of the data by adding a randomly drawn “residual” value to the (conditional) mean. Finally, multiple random “residual” values are drawn for each missing observation to account for the inherent uncertainty of the imputation model. Thus, multiple data sets are created, each containing all of the non-missing values from the original data set, but with different imputed values for each observation that had been missing originally. Standard data analytic methods (here, ANOVA) are applied to each data set separately, and then results are combined using formulas provided by Rubin (1987), leading to a single F -test across imputations.

These analyses indicated that there was a difference among the study conditions’ ratings for all three stimulus types (smallest $F(2,178) = 5.47$, $MSE = 0.33$ for nonwords). Individual paired comparisons showed that ratings were higher for visually- ($F(1,89) = 23.48$, $MSE = 0.65$) and aurally-presented pseudowords ($F(1,89) = 11.09$, $MSE = 0.36$) than new pseudowords. Visually-presented words ($F(1,89) = 11.10$, $MSE = 1.24$) were rated as more likely to have been studied compared to new words, but aurally-presented words were not rated as more likely to have been studied compared to new words ($F < 1$), although there was a mean trend in that direction ($M = 4.04$ and $M = 3.81$ for aurally-presented words and new words, respectively). Visually-presented nonwords were rated as more likely to have been studied compared to new nonwords ($F(1,89) = 9.81$, $MSE = 0.18$), but aurally-presented nonwords were not rated as more likely to be studied compared to new nonwords ($F(1,89) = 1.73$, $MSE = 0.17$, $p < .20$), although there was a mean trend in that direction ($M = 4.83$ and $M = 4.72$ for aurally-presented nonwords and new nonwords, respectively). Finally, there was a modality-match effect for all three types of stimuli (smallest $F(1,89) = 4.37$, $MSE = 0.15$ for nonwords). Thus, unidentified test items showed two data patterns that differed from identified test items. First, nonwords and words only showed recognition without identification when they were studied in the same modality as they were tested, while both aurally- and visually-studied nonwords and words showed increased confidence ratings when they were identified. Second, recognition without identification for words showed a study-test modality match effect, while identified words showed the opposite pattern, such that words studied aurally (study-test mismatch) were recognized with higher confidence than words studied visually (study-test match).

z-ROC analyses

As was done for the data from Experiments 1 and 2, we examined the z -ROCs for unidentified pseudowords and nonwords in an effort to establish that recognition without identification for those two item types occurred due to a simple signal detection process.² As a consequence of how participants distributed their confidence judgments for unidentified items, it was not possible to compute individual z -ROCs for 7 participants’ responses to visually-presented nonwords, 6 participants’ responses to aurally-presented nonwords, 38 participants’ responses to visually-presented pseudowords, and 38 participants’ responses to aurally-presented pseudowords. The number of participants for whom it was not possible to compute z -ROC parameters was higher in this experiment due to the reduced number of items per condition, 20, relative to Experiments 1 and 2, where there were 30 items per condition, as well as the higher identification rates in the pseudoword conditions relative to Experiments 1 and 2. Mean z -ROC slopes and intercepts for nonwords and pseudowords are presented in Table 6.

²We do not report z -ROCs for words for Experiment 3 because the very high identification rates for words meant that very few participants produced sufficient data to compute ROC parameters.

The intercept of the z -ROC was above zero for all conditions, but was only reliably so for the auditory ($t(51) = 2.40$) and visual ($t(51) = 4.02$) pseudoword conditions. The slope of the z -ROC did not differ from 1.0 in the visual-nonword ($t(82) = 0.64$), auditory-nonword ($t(83) = 1.59$), or visual-pseudoword study conditions ($t(51) = 0.02$), but was reliably below 1.0 in the auditory-pseudoword condition ($M = 0.87$; $t(51) = 2.28$). As with Experiments 1 and 2, because the z -ROC intercepts were not reliably above 0.0 for all conditions, we analyzed z -ROC slopes for restricted data sets that ensured z -ROC intercepts were above 0.0 (Hirshman & Hostetter, 2000). In particular, we analyzed only the slopes of participants whose z -ROC intercepts were above 0.0 as well as the slopes of participants whose z -ROC intercepts were above .10. These analyses will also allow us to determine whether the finding that the slope of the z -ROC in the auditory-pseudoword condition was below 1.0 was a general characteristic of that condition. The mean slopes and intercepts for these restricted data sets are presented in the lower two panels of Table 6. In all eight cases, the slope failed to differ from 1.0 (largest $t(44) = 1.40$ for visually presented nonwords), while the intercepts were all reliably above 0.0, as is necessarily the case given these analyses were of data where all participants' z -ROC intercepts were greater than 0.0. Thus, restricting the data that were analyzed to include only cases where the z -ROC intercept was above 0.0 and .10 failed to produce z -ROC slopes that reliably differed from 1.0. These results suggest that familiarity-based representations mediated performance for unidentified items. Further, these results extend the results of Experiments 1 and 2 to conditions where there was a perceptual mismatch between encoding and retrieval.

Finally, we combined the z -ROC slope and intercept data for the visual presentation of nonwords and pseudowords in Experiment 3 with the nonword and pseudoword z -ROCs from Experiments 1 and 2. This analysis was intended to provide a maximally-powerful test of the hypothesis that z -ROC slopes for unidentified items were below 1.0. As with our analyses of each individual experiment, we analyzed z -ROC slope and intercept parameters for all of the nonword and pseudoword data from the three experiments, as well as two subsets of the data that guaranteed z -ROC intercepts were above 0.0. The results of these analyses are presented in Table 7. The important regularity to note is that in all cases, the intercept of the z -ROC was reliably above 0.0, but in none of the cases was the z -ROC slope reliably different than 1.0. Indeed, even for the most restricted data sets, when all participants' z -ROC intercepts were above 0.10, the mean z -ROC slopes were 0.98 for nonwords and 0.99 for pseudowords, despite mean intercepts of 0.51 and 0.49, respectively. In summary, z -ROC analyses of the data from all studies support the hypothesis that recognition without identification for nonwords and pseudowords was mediated by familiarity-based representations.

Discussion

The critical result from Experiment 3 was that matching study and test modality enhanced recognition without identification for nonwords, pseudowords, and words. This result suggests that episodic details, such as study modality, are encoded in the representations that mediate recognition memory familiarity. This result poses a challenge for existing representation theories, which generally predict that there should not have been a modality match effect in any of the conditions. Further, it is particularly problematic that a modality match effect was found for pseudowords and words, which are the stimulus types for which existing representation theories are most capable of explaining recognition without identification. In addition, the results of Experiment 3 pose a problem for Reder et al.'s (2002) explanation of how new conceptual representations form within the framework of an existing representation theory. Recall that this theory suggests that the first time a stimulus is experienced, a weak episodic representation is formed that binds together the features of that stimulus (e.g., the letters in a nonword or pseudoword) and its presentation characteristics (e.g., modality). This representation could then be used to mediate familiarity-based performance, such as recognition without identification. Because the representation mediating recognition without

identification was formed during the study episode, it is likely to also have been associated with other features present during that episode, such as the modality in which it was presented. Thus, an elaboration of existing representation theories of familiarity can accommodate the modality match effect for nonwords and pseudowords. However, this theory encounters difficulty explaining the finding that there was a modality match effect for words, which should not require the formation of a new, episodically-based representation. As a result, there is no reason this theory would expect modality information to contribute to familiarity for words (see Cleary & Greene, 2000 for similar results with words and study-test modality match).

In contrast, the finding of a modality-match effect for nonwords, pseudowords, and words is a cardinal prediction of episodic representation theories of familiarity. According to episodic representation theories, familiarity-based representations should include details of study item presentation, such as the modality in which those items were encoded. Thus, when the modality between study and test matches, familiarity should increase relative to when the modality between study and test does not. Further, because familiarity for nonwords, pseudowords, and words is assumed to arise from matching test probes to episodic representations, all three item types should show a modality match effect, exactly the result observed in this experiment. However, not all of the results from Experiment 3 are readily explained by episodic representation theories. In particular, episodic representation theories expect the representations underlying familiarity to be similar for all three word types. Consequently, it is not clear why nonwords and words did not show recognition without identification following auditory study, but pseudowords did. While we do not wish to make strong claims regarding recognition without identification for words and nonwords when study and test modality mismatched, two considerations suggest it is reasonable to expect these results are not overly problematic for episodic representation views. First, the means in the auditory study conditions of Experiment 3 for all three stimulus types were in the direction of showing enhanced recognition without identification, even though the difference was only reliable for pseudowords. Second, prior work (Cleary & Greene, 2000) has shown evidence that auditory study produces recognition without identification for visually-tested words. Thus, we expect that future research is likely to find evidence of both a modality match effect in recognition without identification for nonwords, pseudowords, and words, replicating the present results, as well as recognition without identification for all three stimulus types when study and test modality mismatch.

General Discussion

This paper reported three studies examining recognition without identification for items that can be assumed to have a pre-existing representation (words) as well as items that are unlikely to have a pre-existing representation (nonwords, and possibly pseudowords). The overall results of these studies showed that recognition without identification occurs for all three types of stimuli, consistent with prior results suggesting that familiarity can mediate novel learning (Gardiner & Java, 1990; Yonelinas & Jacoby, 1995). Further, recognition without identification for all three types of stimuli showed a modality-match effect. This latter result is consistent with the hypothesis that the representations underlying recognition without identification are episodic in nature, as has been suggested in prior theoretical treatments of recognition without identification (e.g., Cleary & Greene, 2001). Importantly, the modality-match effect for all three stimulus types is not readily explained by theories that claim familiarity is mediated by increasing the activation of existing representations (e.g., Atkinson & Juola, 1973; Reder, et al., 2000; 2002).

One particular type of episodic representation theory that has been used to explain recognition without identification is a global matching model (Cleary & Greene, 2001). Recall that global-matching models suggest that recognition without identification results from partial matching

of test items to representations in memory. This explanation suggests that when a test item is not identified accurately, it is nevertheless likely that some of the features of the test stimulus (e.g., letters and letter positions) were extracted by the participant during the identification trial. This impoverished stimulus information can then be used to construct a memory probe to evaluate whether the flashed stimulus was studied. Items that were studied will tend to produce memory probes that match the contents of memory slightly better than items that were not studied, producing slightly higher confidence judgments for test items that were studied, but could not be identified, than test items that were not studied and not identified.

The global matching explanation of familiarity processes and recognition without identification can be further tested by considering the number of letters participants were able to report accurately prior to making a recognition judgment. The test task used in these experiments to separate items into identified and unidentified items was a perceptual identification task. Following each stimulus presentation, participants were asked to type the stimulus that was shown to them. In prior studies of recognition without identification using the perceptual identification task, stimuli were simply divided into those that were identified accurately, and those that were not accurately identified (Cleary & Greene, 2004; 2005). However, perceptual identification allows for more fine-grained testing of the global-matching explanation of recognition without identification than has been reported previously. In particular, the explanation of recognition without identification derived from global-matching models is that participants use the information about letters and letter positions to construct a partial test probe, which they then match to the contents of memory. This explanation suggests that the more information participants were able to extract from a perceptual identification trial, the better the recognition memory probe they can construct, and consequently the greater the accuracy of their judgment of the item's studied status should be. Thus, if judgments of the likelihood that a test item was studied are analyzed as a function of the number of letters accurately placed in their proper position on the perceptual identification trial, global-matching models predict judgments for unidentified studied and unstudied items should diverge as more letters are perceived in the correct position.³

To test this prediction, we examined whether recognition without identification occurred when participants were able to identify none of the letters in a test item and whether recognition without identification occurred when participants were able to identify the majority of a test item. We scored each identification trial for nonwords and pseudowords for the number of letters a participant accurately identified in the correct position. Thus, unidentified test items were classified as having 0, 1, 2, or 3 letters correctly identified. Further, we restricted these analyses to unidentified pseudowords and nonwords in Experiment 1, Experiment 2, and the visual study condition of Experiment 3 because those were the conditions that all showed evidence of recognition without identification. Given that classification was determined by participant identification performance, it was not always the case that every participant produced a data point in each of the sixteen cells of the resulting classification scheme (0–3 letters identified; old or new test item; test item was a pseudoword or nonword). Indeed, this classification produced 636 missing data points across the three experiments out of 2592 possible data points (162 participants $\times$ 16 data points per participant), approximately 25% missing data. However, 121 of the 162 participants had at least one cell of data missing. Thus, simply eliminating subjects who did not produce at least one observation in every cell would have substantially sacrificed statistical power. As with analyses of unidentified item ratings in Experiment 3, we again used multiple imputation (Rubin, 1987) to complete the cells where data were missing.

³We thank Bill Hockley for making this observation.

In order to derive as powerful of a test as possible, we combined the data for pseudowords and nonwords from the first two experiments with the visual study condition from the third experiment. We then compared studied and unstudied test item ratings when participants were able to identify no letters to when they were able to identify two or three of the four letters in a stimulus in the correct position. In the case where no letters were identified, global-matching models predict that participants should not show a difference in their ratings for studied and unstudied test items, because they are using a recognition memory probe that does not match an actual representation in memory. On the other hand, global matching models suggest that when a person was able to accurately identify two or three letters in the correct position, their recognition memory probe should bear some similarity to a representation in memory, and they should therefore show recognition without identification. The results of these analyses, presented in Figure 1 (nonwords) and Figure 2 (pseudowords), supported the prediction of global-matching models of familiarity. Specifically, there was an interaction between the number of letters identified in a test item (0 vs. 2 or 3) and the studied status of the test item (old vs. new) for both pseudowords ($F(1,161) = 8.69$, $MSE = 1.95$) and nonwords ($F(1,161) = 11.19$, $MSE = 2.17$). As is evident in Figure 1 and Figure 2, these interactions indicate that studying a stimulus increased confidence ratings when a participant was able to identify two or three letters during the perceptual identification trial, but that no such increase occurred when they were unable to accurately identify any letters during the perceptual identification trial. Simple comparisons supported this interpretation of the data. When participants were unable to accurately identify any letters from a test item, they failed to show reliable evidence of recognition without identification for pseudowords ($F(1,161) = 1.93$, $MSE = 2.52$, $p > .15$), and showed higher ratings for *new* nonwords than old nonwords ($F(1,161) = 4.87$, $MSE = 3.63$). In contrast, when participants were able to accurately identify two or three letters from a test item, they showed recognition without identification (i.e., higher ratings for *old* than new items) for both pseudowords ($F(1,161) = 36.64$, $MSE = 1.35$) and nonwords ($F(1,161) = 8.58$, $MSE = 0.99$). Thus, fine-grained analyses of the present data provide strong support for global-matching models of familiarity (Hintzman, 1988; Shiffrin & Steyvers, 1997) as well as the global-matching explanation of recognition without identification (Cleary & Greene, 2001; 2005). Coupled with the finding that recognition without identification for nonwords and pseudowords, as well as the finding of a modality match effect for recognition without identification for all three item types, the data from these three studies strongly support global-matching explanations of recognition memory familiarity.

Although the results of these studies favor episodic representation theories of familiarity processes, it is important to note that they do not rule out the possibility that abstract, generalized representations also contribute to recognition memory familiarity. Indeed, ample evidence exists, both from the present studies, as well as from prior studies, that not all familiarity is episodically-based. Regarding the present studies, recognition without identification was observed for pseudowords that were studied aurally, but tested visually. Similarly, prior research has shown that when words are presented aurally, but tested visually, recognition without identification still occurs (Cleary & Greene, 2000). The present Experiment 3 produced condition means that were consistent with the results of Cleary and Greene (2000), although confidence ratings in the auditory study condition did not reliably differ from confidence ratings for unstudied items. Further, recognition without identification occurs for critical lures in the Deese-Roediger-McDermott paradigm (Cleary & Greene, 2004; Deese, 1959; Roediger & McDermott, 1995), which suggests that stimuli need not be directly perceived (aurally or visually) in order for familiarity to be incremented. Finally, recognition without identification occurs for answers to general knowledge questions, even when the answers were studied in isolation (i.e., in the absence of the general knowledge question to which they are the answer; Cleary, 2006). All of these results suggest that there are components of familiarity, as measured by recognition without identification, that are not strictly episodic in nature. Consequently, it is most reasonable to regard the results of the present studies as

evidence that episodic information *can* contribute to familiarity, but that episodic information is *not the sole basis* of familiarity.

In closing, we wish to echo the suggestion of Cleary (2005; see also Cleary & Greene, 2005) that recognition without identification is a useful technique for studying familiarity processes in recognition. Because recognition without identification provides a measure of familiarity that is relatively uncontaminated by recollection-based processes, it may allow researchers greater flexibility in studying the factors that influence familiarity by allowing direct assessment of the influence of experimental manipulations on familiarity (Cleary, 2005; Cleary & Greene, 2001; 2005). This advantage is significant because the ability of measurement techniques to accurately separate recollection and familiarity is necessarily limited by the validity of their underlying assumptions (Curran & Hintzman, 1997). Alternatively, recognition without identification can function as a converging methodology to verify and extend existing data patterns found with (potentially controversial) measurement techniques such as remember-know judgments. Regardless, recognition without identification has proven useful for our purposes, and we anticipate it will continue to be a beneficial technique for studying the contribution of familiarity to a variety of memory tasks, as well as for testing theories of the representations underlying familiarity processes.

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Figure 1. Mean ratings for nonwords as a function of old vs. new and the number of letters correctly identified in perceptual identification. Error bars indicate the standard error of the mean.

Figure 2.

Mean ratings for pseudowords as a function of old vs. new status and the number of letters correctly identified in perceptual identification. Error bars indicate the standard error of the mean.

Table 1

Mean proportion of studied and unstudied items identified on the perceptual identification task in Experiments 1 and 2 as a function of stimulus type. Standard Error of the Mean is in parenthesis.

	Studied Status	
	Old	New
<i>Experiment 1</i>		
Word	.30 (.05)	.18 (.04)
Pseudoword	.26 (.05)	.16 (.03)
Nonword	.24 (.04)	.19 (.03)
<i>Experiment 2</i>		
Word	.74 (.04)	.64 (.05)
Pseudoword	.29 (.04)	.14 (.02)
Nonword	.22 (.03)	.15 (.02)

Table 2

Mean ratings for identified and unidentified items in Experiments 1 and 2 as a function of stimulus type and whether the stimulus was studied. Standard Error of the Mean is in parenthesis.

	Identified		Unidentified	
	Old	New	Old	New
<i>Experiment 1</i>				
Word	6.91 (.30)	5.02 (.42)	3.79 (.30)	3.81 (.27)
Pseudoword	6.77 (.35)	3.42 (.37)	3.74 (.26)	3.22 (.21)
Nonword	6.12 (.31)	5.35 (.34)	4.97 (.26)	4.66 (.24)
<i>Experiment 2</i>				
Word	6.63 (.23)	3.25 (.20)	4.37 (.30)	3.62 (.28)
Pseudoword	6.37 (.35)	4.18 (.36)	3.71 (.20)	3.43 (.20)
Nonword	6.62 (.41)	4.97 (.39)	4.47 (.29)	4.17 (.21)

Table 3
Mean z-ROC slopes and intercepts for unidentified items in Experiments 1 and 2 as a function of stimulus type and minimum z-ROC intercept. Standard Error of the Mean is in parenthesis.

Stimulus Type		Experiment	Slope	Intercept	N	t_{slope}	t_{int}
All Data							
Word	Exp. 1	0.97 (.11)	-0.14 (.11)	27	0.27	1.32	
	Exp. 2	1.04 (.20)	0.19 (.12)	20	0.19	1.62	
Pseudoword	Exp. 1	0.98 (.11)	0.26 (.13)	23	0.16	1.99	
	Exp. 2	0.94 (.05)	0.09 (.06)	34	1.23	1.64	
Nonword	Exp. 1	1.02 (.05)	0.13 (.06)	32	0.41	2.08*	
	Exp. 2	0.98 (.04)	0.15 (.07)	34	0.51	2.21*	
Intercepts > 0.0							
Word	Exp. 1	1.28 (.21)	0.38 (.10)	10	1.33	3.72*	
	Exp. 2	1.01 (.27)	0.43 (.11)	14	0.05	3.80*	
Pseudoword	Exp. 1	1.04 (.13)	0.45 (.13)	17	0.31	3.51*	
	Exp. 2	0.95 (.06)	0.26 (.04)	24	0.77	7.16*	
Nonword	Exp. 1	1.04 (.05)	0.38 (.08)	17	0.83	4.61*	
	Exp. 2	0.98 (.06)	0.31 (.08)	22	0.36	8.20*	
Intercepts > .10							
Word	Exp. 1	1.30 (.30)	0.46 (.13)	7	1.00	3.66*	
	Exp. 2	1.02 (.32)	0.49 (.12)	12	0.05	3.97*	
Pseudoword	Exp. 1	1.06 (.14)	0.50 (.14)	16	0.44	3.54*	
	Exp. 2	0.93 (.07)	0.31 (.04)	20	0.96	8.91*	
Nonword	Exp. 1	1.04 (.04)	0.50 (.09)	12	0.98	5.30*	

Stimulus Type	Statistic				<i>N</i>	<i>t_{slope}</i>	<i>t_{int}</i>
	Experiment	Slope	Intercept				
	Exp. 2	1.02 (.08)	0.47 (.11)		14	0.23	4.85*

Note: Sample size for each slope and intercept is indicated in the “*N*” column. The “*t_{slope}*” column indicates the *t*-statistic for the hypothesis test that the slope is different from 1.0; the “*t_{int}*” column reports the *t*-statistic for the hypothesis that the intercept is different than 0.0.

* *p* < .05, two tailed.

Table 4

Mean proportion of studied and unstudied items identified on the perceptual identification task in Experiment 3 as a function of study modality and stimulus type. Standard Error of the Mean is in parenthesis.

	Study Modality		
	Visual	Auditory	New
Word	.82 (.02)	.81 (.02)	.70 (.02)
Pseudoword	.67 (.03)	.58 (.03)	.52 (.03)
Nonword	.35 (.02)	.29 (.02)	.28 (.02)

Table 5
Mean ratings for identified and unidentified items in Experiment 3 as a function of study modality and stimulus type. Standard Error of the Mean is in parenthesis.

	Identified			Unidentified		
	Visual	Auditory	New	Visual	Auditory	New
Word	6.38 (.15)	7.73 (.10)	3.70 (.15)	4.58 (.24)	4.04 (.20)	3.81 (.15)
Pseudoword	7.17 (.12)	6.36 (.13)	4.47 (.16)	4.66 (.16)	4.31 (.12)	3.84 (.13)
Nonword	6.48 (.17)	5.72 (.16)	5.36 (.17)	5.00 (.11)	4.83 (.11)	4.72 (.12)

Table 6
Mean z-ROC slopes and intercepts for unidentified items in Experiment 3 as a function of stimulus type, study modality, and minimum z-ROC intercept. Standard Error of the Mean is in parenthesis.

Stimulus Type	Study Modality	Statistic					
		Slope	Intercept	N	T_{slope}		
<hr/>							
All Data	Nonword	Visual	0.96 (.06)	0.08 (.04)	83	0.64	1.74
		Auditory	0.94 (.04)	0.05 (.04)	84	1.59	1.12
	Pseudoword	Visual	0.99 (.11)	0.32 (.08)	52	0.09	4.02 *
		Auditory	0.87 (.06)	0.17 (.07)	52	2.28 *	2.40 *
<hr/>							
Intercepts > 0.0	Nonword	Visual	0.92 (.06)	0.34 (.06)	44	1.40	6.19 *
		Auditory	0.92 (.06)	0.34 (.04)	44	1.34	8.09 *
	Pseudoword	Visual	0.97 (.13)	0.53 (.08)	38	0.23	6.41 *
		Auditory	0.98 (.08)	0.47 (.08)	31	0.23	5.84 *
<hr/>							
Intercepts > .10	Nonword	Visual	0.99 (.06)	0.46 (.04)	34	0.17	12.27 *
		Auditory	0.94 (.05)	0.38 (.04)	37	1.38	8.39 *
	Pseudoword	Visual	0.99 (.14)	0.55 (.09)	36	0.11	6.45 *
		Auditory	1.00 (.09)	0.51 (.09)	28	0.03	6.01 *

Note: Sample size for each slope and intercept is indicated in the “N” column. The “ t_{slope} ” column indicates the t -statistic for the hypothesis test that the slope is different from 1.0. the “ t_{int} ” column reports the t -statistic for the hypothesis that the intercept is different than 0.0.

* $p < .05$, two tailed.

Mean z-ROC slopes and intercepts for unidentified items in all experiments (visual study, visual test) as a function of stimulus type and minimum z-ROC intercept. Standard Error of the Mean is in parenthesis.

Stimulus Type		Statistic			N	t_{slope}	t_{int}
	Slope	Intercept					
<hr/>							
<i>All Data</i>							
Nonword	0.97 (.04)	0.13 (.04)		151	0.78	3.53 *	
Pseudoword	0.98 (.06)	0.24 (.05)		108	0.39	4.83 *	
<hr/>							
<i>Intercepts > 0.0</i>							
Nonword	0.94 (.05)	0.36 (.05)		89	1.28	7.75 *	
Pseudoword	0.98 (.07)	0.44 (.05)		80	0.30	8.65 *	
<hr/>							
<i>Intercepts > .10</i>							
Nonword	0.98 (.06)	0.51 (.05)		62	0.26	10.00 *	
Pseudoword	0.99 (.08)	0.49 (.05)		71	0.12	9.08 *	

Note: Sample size for each slope and intercept is indicated in the “N” column. The “*t_{slope}*” column indicates the *t*-statistic for the hypothesis test that the slope is different from 1.0, the “*t_{int}*” column reports the *t*-statistic for the hypothesis that the intercept is different than 0.0.

* *p* < .05, two tailed.