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Vancouver, Toronto, Montreal, Austin: Enhanced oddball memory through differentiation, not isolation

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What makes a person, event, or object memorable? Enhanced memory for oddball items is long established, but the basis for these effects is not well understood. The present work clarifies the roles of isolation and differentiation in establishing new memories. According to the isolation account, items that are highly dissimilar to other items are better remembered. In contrast, recent category learning studies suggest that oddball items are better remembered because they must be differentiated from similar items. The present work pits the differentiation and isolation accounts against each other. The results suggest that differentiation, not isolation, leads to more accurate memory for deviant items. In contrast, gains for isolated items are attributable to reduced confusion with other items, as opposed to preferential storage.

Vancouver, Toronto, Montreal, Austin: Given a list of items to remember, people show a memory advantage for an item that differs from others in some way, such as an American city (Austin) in a list of Canadian cities (Vancouver, Toronto, Montreal). This robust memory phenomenon is known as the *von Restorff effect* (von Restorff, 1933) and has been established in various forms. For example, deviant faces (Valentine, 1991), behaviors (Stangor & McMillan, 1992), and category members (Palmeri & Nosofsky, 1995) result in enhanced memory. Whether or not information is deviant depends on how humans structure their environment (Schmidt, 1991). In the example above, people discover the structure that most list items are Canadian cities. Austin is novel in the context of this structure.

Novelty detection is the flip side of stimulus generalization and likely plays a central role in our mental development. Indeed, infants tend to show preference for a novel stimulus once they habituate to a familiar one (Fantz, 1964), and this ability to respond to novelty is predictive of later intelligence (McCall & Carriger, 1993). Novelty affects our mental activities. For instance, deviant individuals are judged as more influential than others, and more behaviors of deviant individuals are remembered (Taylor, Fiske, Etcoff, & Ruderman, 1978). Research in cognitive neuroscience has focused on identifying the neural circuits underlying novelty processing (see, e.g., Kishiyama, Yonelinas, & Lazzara, 2004; Ranganath & Rainer, 2003).

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Despite the widespread interest in novelty effects, the basis for these effects is not well understood. Earlier explanations emphasized differential attention allocated to oddball items at the time of encoding (e.g., Jenkins & Postman, 1948). However, these explanations have been challenged by work demonstrating memory advantages for deviant items presented at the beginning of a study list (e.g., Kelley & Nairne, 2001). More recent explanations focus on the processing of similarities and differences among stimulus items (Fabiani & Donchin, 1995; Hunt & Lamb, 2001; Nairne, 2006). According to Hunt and Lamb, oddball items, which differ from other items, become isolated by grouping of other items that share similarities.

In the present work, we examine the role of similarity among deviant and other items in enhanced memory. Most explanations center on the advantage conferred to isolated items (see, e.g., Hunt & Lamb, 2001). In the isolation account, deviant items are better remembered when they are more dissimilar to other items. Highly dissimilar items occupy an isolated region in a representational space (Busey & Tunnicliff, 1999) and do not activate many stored items during retrieval (Nairne, 2006). The isolation account attributes novelty effects to reduced confusion with other items.

However, recent category learning research has brought the isolation account into question and suggested instead that differentiation underlies the enhanced oddball memory (Sakamoto & Love, 2004). Interitem similarity relations play opposing roles in these two accounts. In the differentiation account, oddball items are remembered better when they are more similar to other items. Items that are highly similar to other items yet deviate on a property are stored in a dense region and highly confusable with other items. The differentiation account attributes novelty effects to finer-grained memory traces resulting from an

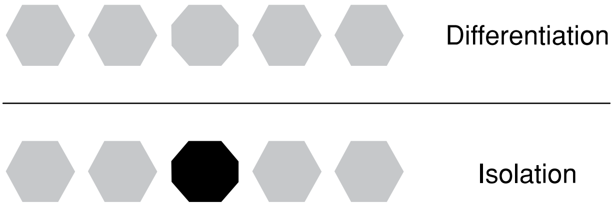

Figure 1. Examples of differentiation and isolation. The top octagon is more differentiated, whereas the bottom octagon is more isolated.

item's contrast with highly similar items that establish a context. In support of the differentiation account, people notice changes in deviant items more accurately (Goodman, 1980) and store more item-specific information of deviant items (Schmidt, 1985).

The isolation and differentiation accounts have not been distinguished from each other in previous research. One reason is that oddball items are usually not only isolated but also differentiated. In Figure 1, for example, the octagons in the top and bottom panels are both isolated in that they have a shape that the hexagons do not have. Both octagons are also differentiated in that they share properties with the other items (e.g., size) but deviate on shape. However, the two octagons differ in their degrees of isolation and differentiation. The top octagon is more differentiated, since it has the same color as the other items, whereas the bottom octagon is more isolated, since its color is dissimilar to that of the other items.

In the present work, we pitted the isolation and differentiation accounts of enhanced memory against each other by varying interitem similarity relations. To foreshadow our results, we mention that isolation and differentiation manipulations lead to qualitatively different memory advantages. As the differentiation account predicts, finer-grained memory traces result for deviant items that are similar to other items. As the isolation account predicts, deviant items that are dissimilar to other items are better identified. The results from two experiments resolve apparent contradictions in the literature by teasing apart the roles of isolation and differentiation in novelty effects.

EXPERIMENT 1

In Experiment 1, we evaluated the contributions of isolation and differentiation to enhanced oddball memory. Subjects learned to classify 10 lines (left panel of Figure 2) varying in color (red or green) and length into Category A or B through sequential presentation with corrective feedback. Most items followed an imperfect rule. For example, red items tended to be in Category A, whereas green items tended to be in Category B. One exception (i.e., oddball) item in each category violated this regularity.

The exceptions were manipulated in a within-subjects design. One exception was highly similar to other items and more differentiated (BX in Figure 2), whereas the other exception was highly dissimilar to other items and more isolated (AX in Figure 2). To eliminate possible influences of absolute line length on performance (Ono, 1967), the subjects were randomly assigned to either the condition on the left in Figure 2, in which the differentiated exception was longer than the isolated exception, or the condition on the right, in which the isolated exception was the longer item. The assignments of color values and category memberships were also random for each subject.

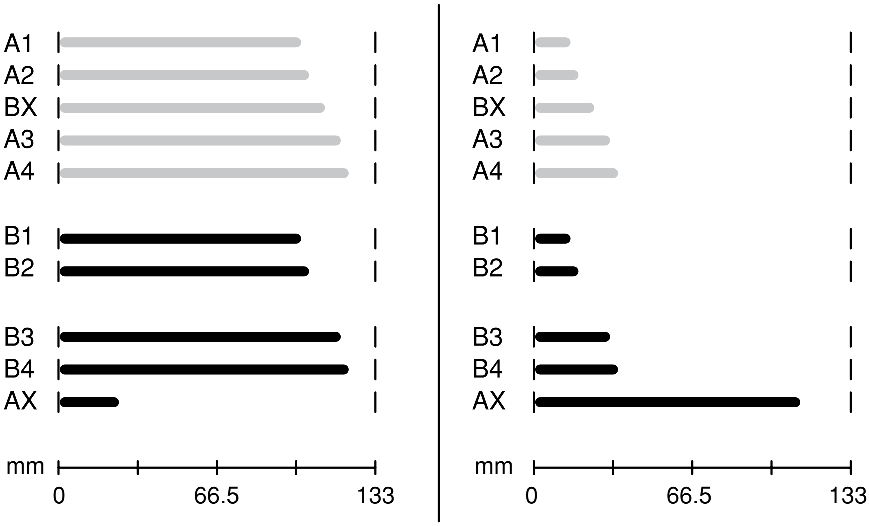

Figure 2. Stimuli used in Experiment 1. Most items follow an imperfect rule. In this case, red items (reproduced in gray here) tend to be in Category A, whereas green items (reproduced in black here) tend to be in Category B. Each category contains an exception. Item BX is more differentiated than Item AX, whereas Item AX is more isolated than Item BX. The subjects were randomly assigned to either the condition on the left, in which the differentiated exception was longer than the isolated exception, or the condition on the right, in which the isolated exception was the longer item.

The differentiation account predicts that subjects will develop high-fidelity representations for the differentiated exception to reduce confusions with similar items from the opposing category. In contrast, the isolation account predicts that memory should be best for the isolated exception due to its dissimilarity to other items. These accounts are evaluated using memory measures following learning.

Method

Subjects. Seventy-eight University of Texas undergraduates participated for course credit.

Procedure. On each learning trial, one stimulus appeared around the center of the monitor. An imperfect rule appeared above the stimulus because our interest was in the subjects' memory for the exceptions (cf. Palmeri & Nosofsky, 1995). After responding "Category A" or "Category B," the subjects received corrective feedback. The subjects completed either 20 blocks or 2 consecutive error-free blocks, whichever occurred first. In each block, each item was presented once in a random order.

There was a filler phase consisting of three arithmetic problems to prevent rehearsal of information from the learning phase. Each problem consisted of two randomly generated integers from 10 to 49. The subjects received corrective feedback after responding.

The subjects then reconstructed the lengths of the differentiated and isolated exceptions from the learning phase. The reconstruction task measures how accurately the exceptions are remembered and, unlike old/new or forced choice recognition tasks, does not involve setting a criterion for the choice response because subjects simply reproduce the length. The subjects were not informed about the reconstruction task prior to the learning phase. On each reconstruction trial, a line appeared around the center of the monitor with its initial length midway between the actual lengths of the two exceptions (66.5 mm). The line's color and membership were given. The subjects were informed that the line was an exception. Each exception was reconstructed three times, and the three reconstructed forms were presented in alternation on successive trials.

Following another filler phase, the subjects classified the 10 learning items without corrective feedback. The transfer classification measures the subjects' ability to identify the exceptions. The procedure for the transfer phase was identical to that for the learning phase except that no rule or corrective feedback was provided. The subjects completed two transfer blocks.

Results

Four subjects did not meet the criterion before completing 20 blocks. As predicted, in the learning phase the subjects classified the isolated exception more accurately than the differentiated exception [.82 vs. .43, respectively; $t(77) = 15.04$, $p < .001$]. The differentiated exception was surrounded by highly similar items and was harder to master than the isolated exception.

Reconstruction error was measured as the absolute difference between the reconstructed length and the actual length. In consistency with the differentiation account, the mean reconstruction error (averaged across three trials) was smaller for the differentiated than for the isolated exception [2.5 vs. 6.1 mm, respectively; $t(77) = 6.64$, $p < .001$]. Figure 3 displays the probability distribution of the subjects' reconstruction responses for the two exceptions. More reconstructions centered around the actual value (i.e., they had a difference of 0) for the differentiated exception than for the isolated exception, suggesting that the subjects developed higher fidelity representations for the former than for the latter.

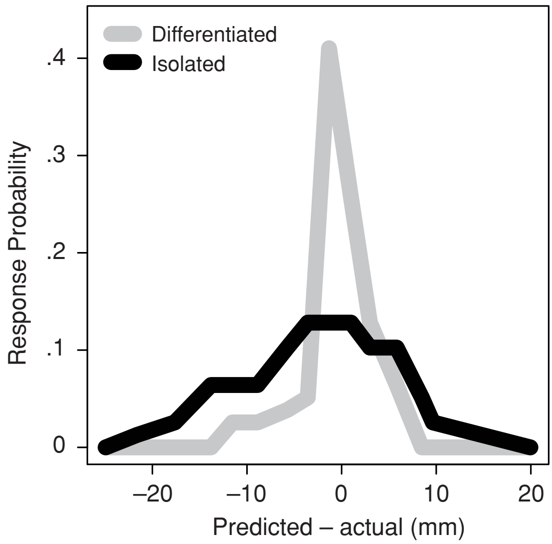

Figure 3. Probability distributions of the subjects' responses for the differentiated and isolated exceptions in the reconstruction phase of Experiment 1. The *x*-axis represents the difference (in millimeters) between length as predicted by the subjects and the actual length. Positive values (i.e., predicted length − actual length > 1) indicate overshoot, whereas negative values indicate undershoot.

Although the subjects reconstructed the differentiated exception more accurately, their transfer classification performance was better for the isolated than for the differentiated exception [.90 vs. .78, respectively; $t(77) = 3.19$, $p < .01$]. In consistency with the isolation account, the isolated exception was less confusable and better identified.

EXPERIMENT 2

In Experiment 1, the isolated item was not only the most dissimilar item but also the most extreme by virtue of being the shortest or longest line, depending on condition. Thus, in the reconstruction task, a response bias toward the average of items sharing the rule dimension value (or the average of all items) could lead to more accurate memory for the differentiated item in Experiment 1. The response bias account predicts the same reconstruction performance for isolated and differentiated items in Experiment 2. The isolated and differentiated exceptions in Experiment 2 are both centroids of the items sharing the rule dimension values, but, as in Experiment 1, the differentiated exception is more confusable with near members of the contrasting category (see Figure 4). Other than this change, Experiment 2 is identical to Experiment 1.

The main results mirrored those of Experiment 1. In the learning phase, 82 University of Texas undergraduates classified the isolated exception more accurately than the differentiated exception [.66 vs. .60, respectively; $t(81) = 2.89$, $p < .01$]. The reconstruction error was smaller for the differentiated than for the isolated exception [2.1 vs. 2.7 mm, respectively; $t(81) = 3.37$, $p < .01$]. More reconstructions centered on the actual value for the differ-

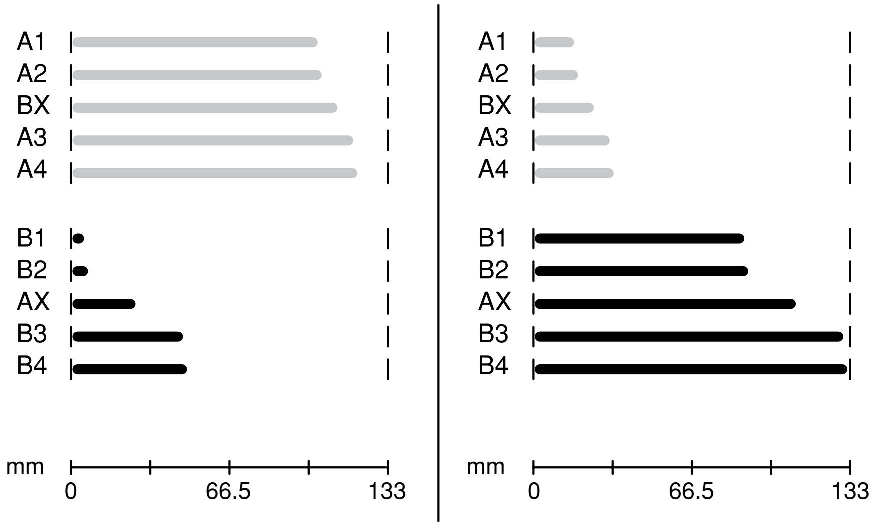

Figure 4. Stimuli used in Experiment 2. As in Experiment 1, two exceptions (one relatively isolated, one relatively differentiated) violated an imperfect rule and the subjects were randomly assigned to either the condition on the left, in which the differentiated exception (BX) was the longer item, or to the condition on the right, in which the isolated exception (AX) was the longer item.

entiated exception, as is shown in Figure 5. In the transfer phase, the isolated exception, despite being less accurately remembered, was classified more accurately than the differentiated exception [.91 vs. .77, respectively; $t(81) = 3.89$, $p < .001$].

The reconstruction results suggest that the more accurate reconstruction for the differentiated item is due to finer-grained representations, not simply to a response bias toward the average of items sharing the rule dimension value. Furthermore, there was no tendency for subjects in either Experiment 1 or Experiment 2 to terminate their response before reaching the target value more often for the isolated than for the differentiated item, suggesting that the advantage displayed by the differentiated item is not attributable to the subjects' being more lax in reconstructing the isolated item.

GENERAL DISCUSSION

In Experiments 1 and 2, we evaluated two explanations for enhanced oddball memory. In both experiments, isolation and differentiation led to qualitatively different memory enhancements. As predicted by the differentiation account, the differentiated exception was more accurately reconstructed. However, as predicted by the isolation account, the isolated exception was better identified.

Whereas the accuracy with which an item is represented underlies reconstruction, what determines identification is how separated an item's representation is from that of others (cf. Nairne, 2006). The differentiated exception was contrasted with highly similar rule-following items from the competing category during learning. The differentiated exception's near neighbors spurred its more finely grained encoding. However, finer-grained representations do not necessarily lead to better identification because identification performance is reduced by confusion with near neighbors. The differentiated exception was difficult to identify because, although it was stored more accurately, its representation was not clearly separated from the representations of its near neighbors. In contrast, the isolated exception was stored in isolation and was better identified.

The differentiation account relates to contextual interference effects in which interference during learning (e.g., in the form of simultaneous presentation of competing stimuli) could facilitate retention (Batting, 1979). In the present experiments, competing items were more similar to the differentiated exception than to the isolated exception. Items with more contextual interference require deeper processing and, once mastered, are better remembered. Likewise, deviant items tend to be processed more fully and deeply because they violate the context and are harder to process (Friedman, 1979).

An alternative view is that error rates during learning drove the present results. The subjects in both experiments made more errors classifying the differentiated than the isolated exception. Similarity and confusability are the catalysts of differentiation and also beget classification errors. However, errors and differentiation are not synonymous. Sakamoto and Love (2004) manipulated the feedback associated with an item and dissociated structure violation and errors during learning. Errors alone did not determine memory performance, and enhanced memory was attributable to structure violation.

Methodological Implications

The present results may help resolve the apparent conflict between studies that uncover isolation advantages and those that do not. Better identification of the isolated

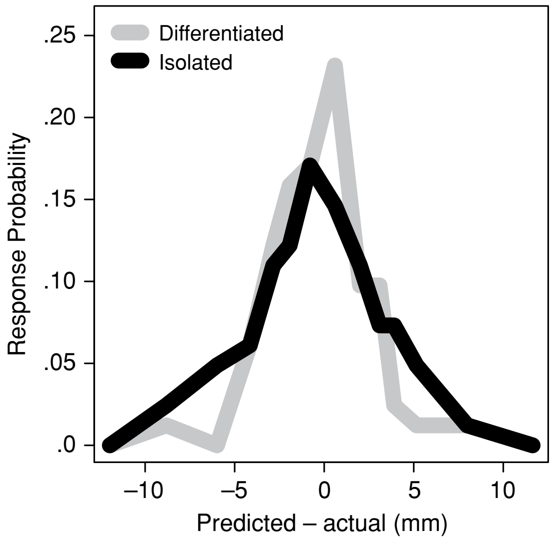

Figure 5. Probability distributions of the subjects' responses for the differentiated and isolated exceptions in the reconstruction phase of Experiment 2. The *x*-axis represents the difference (in millimeters) between length as predicted by the subjects and the actual length. Positive values (i.e., predicted length − actual length > 1) indicate overshoot, whereas negative values indicate undershoot.

exception is attributable to reduced confusion with members of the opposing category rather than to finer-grained representations. Thus, the isolation advantage is likely due to the nature of the other test items and can be eliminated if foil items that are similar to the isolated exception are included in measures of memory performance.

Indeed, studies in which an isolation advantage in old/new recognition was found did not include foils similar to isolated items (Busey & Tunnicliff, 1999; Valentine, 1991). Studies that included foils equally similar to all studied items did not find an isolation advantage (Davidenko & Ramscar, 2004; Zaki & Nosofsky, 2001) unless the isolated items possessed unique item-specific features (Nosofsky & Zaki, 2003). In contrast, the differentiation advantage in reconstruction is not attributable to other test items and instead indicates finer-grained representations for the differentiated exception. In typical memory experiments, as in the present work, subjects gain an appreciation for the structure of the study items during learning. The differentiation advantage should be obtained in tasks other than classification to the extent that subjects discover the structure and master the oddball item.

As the present work has demonstrated, whether an isolation advantage or a disadvantage is observed depends on the nature of the task. Item confusability constrains performance for tasks that yield an isolation advantage, whereas confusability is not harmful, or is even beneficial, for tasks not favoring isolation. Future work in which multiple memory measures are employed and isolation and differentiation are dissociated will be necessary to fully resolve these issues.

Theoretical Implications

Some category learning and memory models utilize novelty-detection mechanisms to gate storage (Metcalfe, 1993; Nosofsky, Palmeri, & McKinley, 1994; Love, Medin, & Gureckis, 2004). For example, Love et al.'s SUSTAIN clustering model forms new clusters in memory when expectation violation occurs (see Rescorla & Wagner, 1972), such as when one learns that bats are mammals and not birds. This mechanism allows SUSTAIN to correctly predict enhanced recognition memory for items that violate a regularity as observed by Palmeri and Nosofsky (1995). Similarly, Nosofsky et al.'s RULEX hypothesis-testing model correctly predicts the recognition advantage for exceptions by explicitly storing items that violate inferred rules.

Sakamoto and Love (2004) modified Palmeri and Nosofsky's (1995) design to tease apart the predictions of cluster- and rule-based accounts and to test the differentiation hypothesis. Sakamoto and Love introduced an asymmetry in the category structures in which one category contained more rule-following items than the other. According to the differentiation account, the exception violating the stronger (i.e., more frequent) regularity has more opportunities for confusion with members of the opposing category, which should lead to finer-grained representations. This result held; it was predicted by SUSTAIN but could not be predicted by RULEX. Rules are insensitive to frequency information (Pinker, 1991), and both differentiated and isolated exceptions violate regularities with the same strength in RULEX.

These results are also inconsistent with exemplar-based accounts, which posit that storage is not novelty gated but, rather, that every training item is stored in memory, and thus do not accord special status to oddball items (but see Sakamoto, Matsuka, & Love, 2004). To determine recognition strength, exemplar models sum the probe item's similarity to all exemplars stored in memory, which favors recognition of typical items. For this reason, identification is modeled as the inverse of summed similarity. As in the retrieval model (Nairne, 2006), the most dissimilar items are least confusable and remembered best (Busey & Tunnicliff, 1999). Of course, this account cannot predict finer-grained representations for differentiated than for isolated exceptions. The critical problem with exemplar models is that, unlike in models utilizing novelty-detection mechanisms, storage is not dependent on items already stored in memory.

Love (2002) presented a clustering model based on SUSTAIN that adjusted each cluster's tuning (related to memory specificity) on each learning trial to minimize prediction errors. This model's dynamics are consistent with the explanations of the present results. The cluster encoding the differentiated exception tends to be activated by the presentation of highly similar rule-following items from the opposing category. To minimize these unwanted activations by items other than the differentiated exception, this cluster becomes highly tuned. The same dynamics govern the isolated exception, but its cluster does not become as specific as the differentiated exception cluster due to the similarity manipulation. Thus, the model will develop finer-grained representations for the differentiated exception but will better identify the isolated exception whose cluster is relatively isolated.

The present results and those from Sakamoto and Love (2004) favor non-rule-based representations of regularities. A central property of rules is their insensitivity to frequency and similarity information (Pinker, 1991). In contrast, factors such as frequency, similarity to other items, and regularity violation drive performance in these tasks, suggesting that storage is gated by novelty whereas mental representations are cluster-like and engaged through similarity-based processing.

Final Note

Novelty effects have been examined in various domains, including the study of schemas and stereotypes (Stangor & McMillan, 1992), list memory (Hunt & Lamb, 2001), face recognition (Valentine, 1991), the neurobiological basis of memory (Kishiyama et al., 2004), and category learning (Sakamoto & Love, 2004). The present work clarifies the contributions of isolation and differentiation in establishing new memories. Differentiation, not isolation, results in more accurate memory for deviant items. Isolation advantages are attributable to reduced confusion with other items rather than to preferential storage.

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