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Perceptual fluency can be used as a cue for categorization decisions.

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BRIEF REPORT

Perceptual fluency can be used as a cue for categorization decisions

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Abstract Learning in the prototype distortion task is thought to involve perceptual learning in which category members experience an enhanced visual response (Ashby & Maddox. *Annual Review of Psychology*, *56*, 149–178, 2005). This response likely leads to more-efficient processing, which in turn may result in a feeling of perceptual fluency for category members. We examined the perceptual-fluency hypothesis by manipulating fluency independently from category membership. We predicted that when perceptual fluency was induced using subliminal priming, this fluency would be misattributed to category membership and would affect categorization decisions. In a prototype distortion task, the participants were more likely to judge stimuli that were not members of the category as category members when the nonmembers were made perceptually fluent with a matching subliminal prime. This result suggests that perceptual fluency can be used as a cue during some categorization decisions. In addition, the results provided converging evidence that some types of categorization are based on perceptual learning.

Keywords Category learning · Priming · Perceptual learning

The prototype distortion task was first introduced by Posner and Keele (1968) as a method of studying how category representations are abstracted and stored. Although variations of the task have been used, in the traditional form of the task, participants are exposed to a series of dot patterns that are distortions of a common prototype, and these distortions form a category. Next, participants judge whether a series of new dot patterns are also category members. The pattern of responses given by participants is thought to reflect the nature of the category representations used to make categorization judgments. More recently, the task has been used to investigate the role of perceptual learning in categorization (e.g., Casale & Ashby, 2008; Coutinho, Couchman, Redford, & Smith, 2010).

A set of fMRI studies involving the prototype distortion task have shown that perceptual learning may be important for abstracting visual prototypes. In three studies (Aizenstein et al., 2000; P. J. Reber, Stark, & Squire, 1998a, 1998b), areas of the occipital cortex showed decreased activity in response to category members relative to nonmembers. This decrease in activation might reflect perceptual learning that leads to easier or more-efficient processing of category members. More specifically, a group of visual cortical cells may learn to respond strongly to the prototype, less to nonprototypical category members, and even less to items that are not in the category. Across the learning period, perceptual learning causes the cells' sensitivity and magnitude of response to increase (Ashby & Maddox, 2005). Because the increased response is only elicited for category members, its presence may be used as a cue to category membership.

If perceptual learning is important for prototype abstraction, then manipulations that affect perceptual learning should also affect categorization performance. Perceptual learning is likely enhanced with categorization training on items that are very similar to the prototype, as compared to training with items that are less similar to the prototype. When participants were trained with highly similar exemplars, their categorization performance was better than when they were trained with less similar exemplars (Casale & Ashby, 2008), suggesting that perceptual learning is important for prototype abstraction.

The enhanced visual response elicited by category members could result in a greater feeling of perceptual fluency (i.e., the feeling of ease or difficulty associated with a

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mental task; Alter & Oppenheimer, 2009; Oppenheimer & Frank, 2008) for category members than for nonmembers. This feeling of fluency may be one cue that is used during judgments of category membership, especially in tasks such as the prototype distortion task (E. Smith, 2008). Perceptual fluency is generally a reliable cue about the state of the environment, but it can be independently manipulated (Alter & Oppenheimer, 2009). For example, subliminal priming, stimulus duration, and stimulus repetition all affect perceptual fluency. Manipulations of perceptual fluency have been shown to affect a range of judgments, including liking (R. Reber, Winkielman, & Schwarz, 1998) and familiarity (Whittlesea, Jacoby, & Girard, 1990).

Perceptual fluency has not been directly manipulated in the context of category-learning tasks, but some studies have pointed to a role for perceptual fluency in semantic categorization. When category exemplars (e.g., *pigeon*, *hummingbird*) were made disfluent by being printed in a small, difficult-to-read font, participants judged them as worse members of a given category (e.g., “bird”) than when they were presented in a larger, easy-to-read font. A feature’s typicality (e.g., “lays eggs”) for a given category was similarly affected by the font in which it was printed (Oppenheimer & Frank, 2008). This experiment illustrated that perceptual fluency is important for categorization judgments of well-learned semantic categories, but it is not clear whether the same would be true during the category-learning process.

In another study, the relationship between prototypicality and fluency was examined using the prototype distortion task (Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). Here, fluency was a dependent variable, measured in terms of categorization speed. It was found that stimuli that were more similar to the prototype were processed more fluently (i.e., more quickly) than stimuli that were less like the prototype. The authors concluded that prototypicality is one of many variables that can affect fluency. However, this study did not manipulate fluency directly. It is possible that prototypical items are categorized more quickly for reasons other than fluency. For example, for prototypical category members that are relatively far from the category boundary, perhaps an approximate computation is sufficient to determine category membership. For less prototypical items that are close to the category boundary, a more precise calculation may be necessary, and this precision may slow the categorization decision. Therefore, it may not be the case that prototypical items are perceived more fluently, but that the categorization decision is easier for items that are farther from the category boundary. A direct manipulation of fluency would rule out this explanation. In addition, the study did not investigate whether the fluency that is associated with prototypicality is used to make a judgment about category membership.

In the present study, fluency was directly manipulated in order to investigate whether it has an effect on categorization decisions. Given that perceptual learning seems to be important for visual prototype abstraction and that perceptual fluency is a cue to perceptual learning, we expected that manipulations of perceptual fluency would affect categorization. Following a training stage in which participants viewed category members, the participants completed a test stage in which they judged whether new items were members of the trained category. In this stage, fluency was manipulated using subliminal priming. Past studies have demonstrated that subliminally priming a stimulus with itself (i.e., a matching prime) elicits a feeling of perceptual fluency relative to priming a stimulus with an unrelated item (i.e., a mismatching prime; Jacoby & Whitehouse, 1989; R. Reber et al., 1998). We expected that items primed with matching primes would be more likely to be endorsed as category members than would items primed with mismatching primes or with no prime, because the fluency experienced as a result of the matching prime would be misattributed to the fluency that coincides with category membership. However, the effect of the prime might differ for category members and nonmembers. If category members elicited a feeling of fluency due to perceptual learning, then additional fluency caused by the matching prime might not affect the categorization of category members, but might still affect categorization of nonmembers.

Experiment 1

Method

Participants A group of 53 participants (37 female, 16 male) from the University of Western Ontario with a mean age of 22.0 years (*SE* = 0.72 years) participated in the study either for course credit or for $5.

Materials The categorization stimuli were similar to the dot patterns that have previously been used to study prototype abstraction (Posner & Keele, 1968; P. J. Reber et al., 1998b), and a detailed description of their construction can be found elsewhere (J. D. Smith & Minda, 2002). The to-be-learned category was created by first generating a prototype and then probabilistically distorting that prototype to create category members that were similar to it. Figure 1 shows the prototype of the category, which was never presented to participants, some distortions of the prototype that were category members, and some randomly generated polygons that were unrelated, noncategorical patterns. The stimuli were presented using E-Prime software (Psychology Software Tools, Inc., Sharpsburg, PA) on a PC with a monitor refresh rate of 60 Hz.

Procedure The study consisted of a training stage, a test stage, and a prime visibility check. In the training stage, the

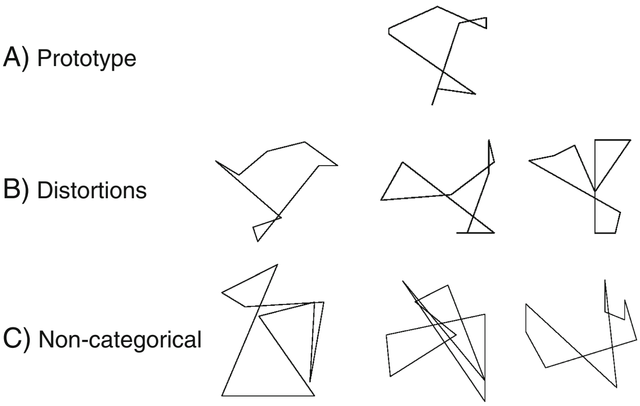

Fig. 1 Shape stimuli used in the experiment. (A) The prototype for the category. (B) Examples of category members that were created by distorting the prototype. A total of 100 distortions of the prototype were created: 40 to be used in the training stage, and 20 to be used as targets in each of three priming conditions in the test stage. (C) Examples of unrelated shapes that were not members of the category. These shapes were all randomly generated, and no distortions were created for any of them. A total of 100 noncategorical polygons were created: 20 to be used as targets in each of the three priming conditions in the test phase, 20 to be used as unrelated primes for category members, and 20 to be used as unrelated primes for category nonmembers in the test phase. The prototype was 182 × 182 pixels. Each of the distortions could be slightly larger or smaller than the prototype, depending on the amount and direction that each point was distorted. Because each polygon was created by randomly selecting points on a grid, the shapes were not necessarily centered on the grid. Each stimulus was manually centered so that all of the stimuli appeared at the center of the screen.

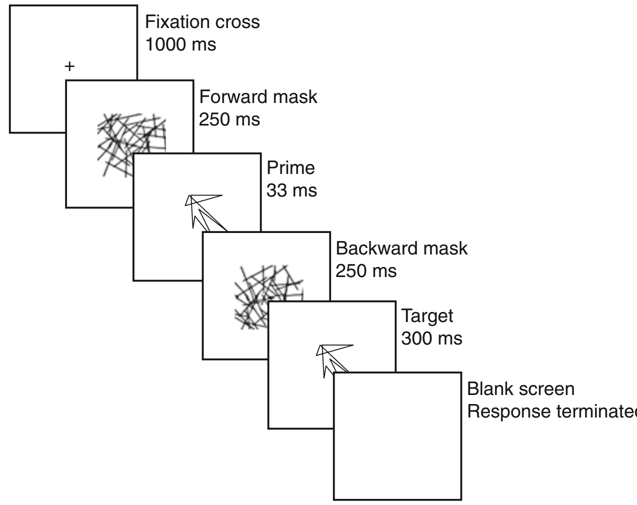

Fig. 2 An illustration of the sequence and timing of events during the test stage and prime visibility stage. In the test stage, participants indicated whether the shape was a member of the category by pushing the "y" key for "Yes" and the "n" key for "No" on a standard USB keyboard. In the prime visibility stage, the participants indicated whether the prime was the same as or different from the target or whether no prime was presented by pushing the "s," "d," or "n" button, respectively.

participants viewed 40 high distortions of the prototype one at a time on the screen for 5 s each. As in prior research, the participants were instructed to imagine pointing at the center of each shape and following the training stage, and they were told that the shapes were members of a single category, in the same way that a series of pictures of dogs would all belong to the "dog" category (Knowlton & Squire, 1993; P. J. Reber et al., 1998b). Next, in the test stage, the participants saw 60 new high distortions of the prototype and 60 unrelated shapes, one at a time, and judged whether each item belonged to the category. Figure 2 illustrates the sequence and timing of events in each of the 120 trials of the test stage. On each trial, a 33-ms masked prime was presented before each to-be-categorized target shape. The prime was the same as the target shape (i.e., a match), was a new, unrelated shape (i.e., a mismatch), or was a blank screen (i.e., no prime). The order of the target shapes was randomized for each participant.

The prime visibility stage was exactly the same as the test stage, except that the participants made judgments about the prime rather than about the target shape. In this stage, the participants were explicitly told that primes appeared between the two masks, and their job was to indicate whether the prime was the same as or different from the target shape, or whether no prime was presented. This stage was included to measure whether the participants had been able to perceive the primes as they were presented in the test stage.

Results and discussion

Prime visibility It was important that the participants not be able to identify the primes, so that any effect of prime type could be attributed to feelings of perceptual fluency rather than to explicit identification strategies. We were most interested in whether the participants were able to identify the content of the prime rather than its presence, so we examined whether the participants' performance at discriminating between matching and mismatching primes was significantly above chance. Six of the participants were able to discriminate between the matching and mismatching primes, so their data were excluded from further analyses. The remaining participants scored an average of 45.68 % correct (*SE* = 2.00 %; chance was 50 %), indicating that the primes were subliminal and that their effect was on feelings of fluency rather than on explicit response strategies.

Categorization performance Categorization performance was calculated as the proportions of correct responses during the test stage. The participants were split into learners and nonlearners, according to whether their categorization performance was significantly above chance. We identified 13 nonlearners, whose average performance was 47.69 % (*SE* = 2.33 %), and 34 learners, whose average performance was 67.50 % (*SE* = 1.12 %), which was similar to performance in other studies (Knowlton & Squire, 1993; P. J. Reber et al., 1998a, 1998b).

We predicted that stimuli primed with matching primes would be more likely to be endorsed as category members than would stimuli primed with mismatching primes or with no prime. If matching primes cause an increase in category endorsement, this would result in an increase in the proportion of correct responses to category members and a decrease in the proportion of correct responses for nonmembers. However, we expected that this might only be true for nonmembers; members might be accompanied by a feeling of fluency, so that additional fluency caused by the primes might not affect categorization performance. We only included learners in our main analysis because we expected that the effect of fluency might be dependent on category membership. Since nonlearners lacked category knowledge, they might not show the predicted fluency effects. The learners' performance, pictured in Fig. 3A, was analyzed using a 2 (category member vs. nonmember) × 3 (prime: match, mismatch, or none) analysis of variance (ANOVA). Category members were categorized less accurately than nonmembers, $F(1, 33) = 9.18$, $p = .005$, $\eta^2 = .22$, reflecting the participants' conservative response strategies. There was no effect of prime, $F(2, 66) = 2.22$, $p = .116$, but there was an interaction between prime type and category membership, $F(2, 66) = 8.05$, $p < .001$, $\eta^2 = .20$, suggesting that the effect of the primes differed depending on category membership. Tukey's HSD tests were used to investigate the effect of prime type separately for category members and nonmembers. For category members, the primes did not affect categorization. This may indicate that category members induced a feeling of fluency and that additional fluency caused by the prime had no effect. For nonmembers, prime type did affect categorization performance. Specifically, performance was lower for stimuli preceded by matching primes than for stimuli that were not primed, $q(3, 66) = 5.79$, $p < .001$, or for stimuli preceded by mismatching primes, $q(3, 66) = 3.76$, $p = .026$. Matching primes caused nonmembers to be processed fluently, resulting in higher rates of category endorsement and lower proportions correct.[1]

Experiment 2

Experiment 2 was an exact replication of Experiment 1, to confirm the reliability of its results.

Method

Participants A group of 45 participants (31 female, 14 male) from the University of Western Ontario with a mean age of 20.2 years (*SE* = 0.45 years) participated in the study either for course credit or for $5.

Materials and procedure The materials and procedure were exactly the same as those used in Experiment 1.

Results and discussion

Prime visibility Seven of the participants were able to discriminate between the matching and mismatching primes, so their data were excluded from further analyses. The remaining participants scored an average of 42.98 % correct (*SE* = 2.29 %).

Categorization performance We identified nine nonlearners, whose average performance was 52.50 % (*SE* = 1.36 %), and 29 learners, whose average performance was 68.19 % (*SE* = 1.02 %). As in Experiment 1, the primary analysis only included learners, whose performance can be seen in Fig. 3B. A 2 (category member vs. nonmember) × 3 (prime: match, mismatch, or none) ANOVA revealed a marginal effect of prime, $F(2, 56) = 3.00$, $p = .058$, and a marginal effect of category, $F(1, 28) = 3.29$, $p = .080$. Just as in Experiment 1, we also found an interaction between prime type and category membership, $F(2, 56) = 10.27$, $p < .001$, $\eta^2 = .27$.

Again, Tukey's HSD tests were used to investigate the effect of prime type separately for category members and nonmembers. As in the first experiment, we found no effect of prime for category members. For nonmembers, performance was lower for stimuli preceded by matching primes than for stimuli that were not primed, $q(3, 56) = 6.21$, $p < .001$, or for stimuli preceded by mismatching primes, $q(3, 56) = 3.53$, $p = .047$.[2]

[1] The corresponding analysis of nonlearners' performance did not show an effect of prime, $F(2, 24) = 3.10$, $p = .064$, or category, $F(1, 12) = 0.01$, $p = .908$, or an interaction between prime and category, $F(2, 24) = 2.96$, $p = .071$. Since nonlearners lacked category knowledge, we did not expect them to exhibit a prime-by-category interaction, because without category knowledge, any effect of prime should be consistent across stimuli. The marginal main effect of prime was not in the predicted direction (match, *M* = 48.27 %; none, *M* = 44.04 %; mismatch, *M* = 50.77 %) and likely would diminish with a larger sample size.

[2] Nonlearners did not show an effect of prime, $F(2, 16) = 1.18$, $p = .334$, or category, $F(1, 8) = 3.02$, $p = .121$, but they did show an interaction between prime and category, $F(2, 16) = 4.40$, $p = .030$, $\eta^2 = .36$. Because the interaction had been nonsignificant in Experiment 1 and was significant in Experiment 2, we also collapsed the nonlearners across experiments and found a significant interaction between prime and category, $F(2, 42) = 6.76$, $p = .003$, $\eta^2 = .24$. There was no effect of prime for nonmembers, but category members primed with a mismatching prime were categorized more accurately (*M* = 51.82 %) than category members primed with a matching prime (*M* = 42.50 %) [$q(3, 42) = 5.58$, $p < .001$] or category members that were not primed (*M* = 44.55 %) [$q(3, 42) = 4.35$, $p = .010$]. That is, disfluency increased categorization performance for members, suggesting that nonlearners may have erroneously associated category members with feelings of disfluency. That nonlearners, who lacked category knowledge, responded to primes differently depending on category membership is puzzling. Furthermore, because the effect of fluency for nonlearners was inconsistent across studies, we cannot make strong conclusions about this effect of fluency in the absence of category knowledge.

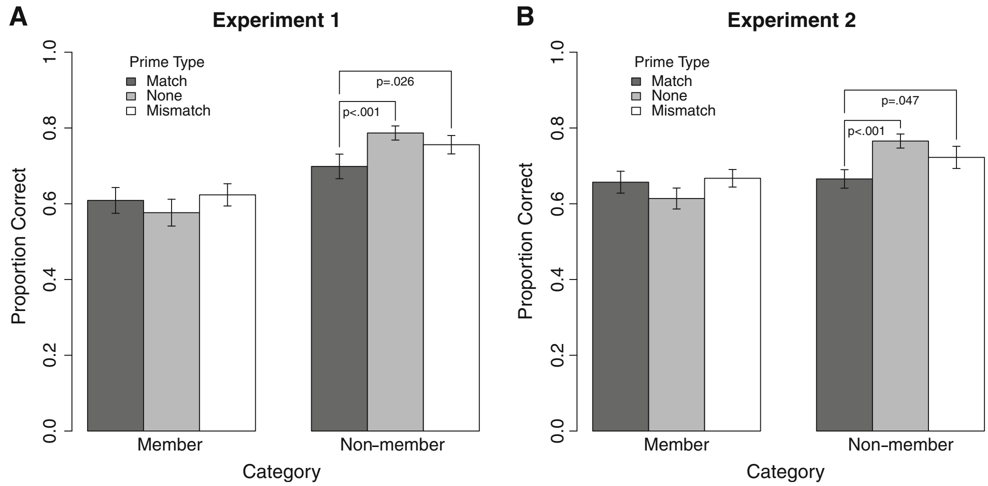

Fig. 3 Proportions of correct categorization responses given by learners for category members and nonmembers with each type of prime for (A) Experiment 1 and (B) Experiment 2. Error bars denote standard errors of the means.

General discussion

In two experiments, we found that categorization judgments were affected by perceptual fluency, but only for stimuli that were not members of the category. Priming nonmembers with matching primes led to a feeling of perceptual fluency, increasing the tendency to incorrectly endorse the stimulus as a category member and causing the proportion of correct categorization responses to decrease. Priming category members did not affect their subsequent categorization. It is likely that perceptual fluency is one of many cues to category membership and that a limit exists as to how much a feeling of fluency can influence a categorization decision. Nonmembers did not produce an enhanced visual response and were not accompanied by a feeling of fluency. When perceptual fluency was induced by priming, it was used as a signal to category membership, and the proportion of items endorsed as category members was increased. Category members, on the other hand, may be accompanied by a feeling of perceptual fluency based on perceptual learning during the training stage. Perhaps the additional feeling of fluency from the matching prime had little effect on the categorization of members because the fluency associated with perceptual learning already had the maximal effect on the categorization decision. In other words, a fluency threshold had already been reached for category members, so the fluency manipulation had no effect on category assignment.[3]

Similar results have been found for the effect of perceptual fluency on recognition memory. Jacoby and Whitehouse (1989) found that perceptual-fluency manipulations had a larger and more robust effect for nonstudied than for studied items. Wolk et al. (2004) carried out an event-related potential study in which the effect of fluency, measured as the size of the N400 during a memory test, was smaller for studied than for nonstudied items. In both cases, the fluency manipulation had a smaller effect for studied items because these items generated their own fluency, and as a result were less susceptible to fluency manipulations, similar to our finding that the existing fluency for category members made further fluency manipulations ineffective.

Although we intended for mismatching primes to induce a feeling of disfluency, they may instead have induced a mild sense of fluency. The mismatching primes were randomly generated nine-point polygons, and as such had some similarity to the category members (i.e., both were constructed of lines and vertices, had similar levels of complexity, etc.). Therefore, the mismatching primes may have conferred a mild processing advantage for the target shapes, rather than the expected disadvantage. This could account for the nonsignificant, although relatively consistent, trend for the mismatching primes to result in performance somewhere between performance with matching primes and with no primes. Although we did not quantify the similarity between the mismatching primes and targets in the present experiments, a logical prediction is that primes can have graded fluency effects, dependent on the similarity between the prime and the target.

If perceptual learning is indeed used during some categorization decisions, manipulations that affect the degree of perceptual learning should also be reflected in categorization decisions. Casale and Ashby (2008) illustrated that performance on the prototype distortion task is best when perceptual learning is strengthened by training participants on stimuli that are highly similar to the category prototype. The length of training could also be manipulated to enhance perceptual learning. Many prototype distortion studies, including our own, use a short training stage, which is not likely to optimize perceptual learning. Future studies could

[3] Note that this does not necessarily imply perfect categorization of category members. While the perceptual-fluency component of the categorization decision might have been maximized, other factors might cause a category member to be incorrectly categorized.

investigate the effects of increased training duration on perceptual fluency in order to determine the effects of perceptual fluency across the learning process.

A recent study provided evidence that low-level perceptual learning is not the only mechanism for prototype learning (Coutinho et al., 2010). When participants were trained on a traditional prototype distortion task, either with stimuli that were all the same size during training and test or with stimuli whose size varied during training and test, performance was comparable in both versions of the task. The authors concluded that low-level perceptual learning is not the only mechanism for prototype learning, because low-level perceptual learning would have been disrupted by variations in size. However, this study did not rule out the possibility that perceptual learning could be the basis of category learning; it only suggested that perceptual learning is not the only mechanism for learning. In addition, the study left open the possibility that higher-level (i.e., nonretinotopic) perceptual learning is the mechanism for prototype learning.

The implications of the present study are likely limited to situations in which participants are trained on a single category. In many categorization studies, including a variant of the traditional prototype distortion task, participants are trained to categorize items as belonging to one of two categories (i.e., Category A or Category B). Perceptual learning may also occur in these types of tasks, but it should not be informative about category membership, as it is in the traditional prototype distortion task (Ashby & Maddox, 2005). In these two-category tasks, all test items should elicit a feeling of fluency, because all of the items are members of a category. Because perceptual learning, and hence perceptual fluency, is present for both categories, it cannot be used in the categorization decision. Therefore, the perceptual-fluency manipulation that affected categorization performance in the present study should not affect performance in a task in which two categories are learned. However, the fluency manipulation might still affect judgments such as the typicality and attractiveness of the stimulus, which are influenced by perceptual fluency.

Conclusion

This study provides the first evidence that feelings of perceptual fluency can be used to make categorization decisions for some newly learned categories. These results provide further evidence that category learning can involve perceptual learning. Future research will be needed to investigate the extent to which perceptual fluency is used for a wider range of categorization decisions.

Author Note Portions of these data were presented at the 33rd annual conference of the Cognitive Science Society.

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