Perceptual Fluency Affects 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, 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 typicality. 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, participants were more likely to judge non-members as category members when they were made perceptually fluent with a matching subliminal prime. This result suggests that perceptual fluency can be reflective of category membership and may be used as a cue during some categorization decisions. In addition, the results provide converging evidence that some types of categorization are based on perceptual learning.

Keywords: Category Learning; Prototype Learning; Perceptual Fluency; Subliminal Priming

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 general form of the task participants are exposed to a series of dot patterns that are distortions of a common prototype and 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 representation used to make categorization judgments. More recently, the task has been used to investigate the role of perceptual learning in categorization (Casale & Ashby, 2008; Coutinho, Couchman, Redford, & Smith, 2010).

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) visual areas in the occipital cortex showed decreased activity in response to category members relative to non-members. The authors suggested that this decrease in activation might reflect easier or faster processing of category members, similar to the type of processing fluency found in repetition priming studies. More specifically, a group of visual cortical cells may learn to respond strongly to the prototype, less to non-prototypical 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 can be used as a cue to category membership.

The perceptual representation system is thought to be an implicit memory system that supports the improved processing of previously seen stimuli, as described above (Schacter, 1990; Tulving & Schacter, 1990). The perceptual representation system is also particularly sensitive to the similarity among stimuli. It can generalize across similar stimuli but not dissimilar stimuli, a process that is important for categorization (Cooper, Schacter, Ballesteros, & Moore, 1992). Consequently, it has been proposed that the perceptual representation system could support the type of perceptual learning that is thought to play a role in abstracting visual prototypes (Casale & Ashby, 2008). In a study where participants were trained on exemplars that were either high or low distortions of the prototype, performance was best after training with the low distortion items. These results illustrate that this type of prototype abstraction is dependent on visual similarity and may be mediated by the perceptual representation system.

Another study investigating the processes underlying prototype learning has come to a slightly different conclusion (Coutinho et al., 2010). In this study, participants were trained on the 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. Therefore, while it seems that some sort of perceptual learning is important for prototype learning, it is not certain that this learning is supported by the relatively low-level perceptual representation system.

Regardless of the level at which perceptual learning occurs, the enhanced visual responding that accompanies category members could be informative of category membership (Ashby & Maddox, 2005). Perceptual fluency is the feeling of ease or difficulty associated with a mental task (Alter & Oppenheimer, 2009; Oppenheimer & Frank, 2008). Because category members experience an enhanced visual response, this could contribute to a feeling of perceptual fluency for category members but not for non-members. This feeling of fluency may be the cue that is used during judgments of category membership, especially in tasks such as the prototype distortion task.

While perceptual fluency is generally a reliable cue about the state of the environment, it can be independently manipulated (Oppenheimer, 2008). For example, subliminal priming, figure ground contrast, stimulus duration and stimulus repetition all affect perceptual fluency. Since perceptual fluency is a feeling that accompanies a range of cognitive activities, manipulations of perceptual fluency have been shown to affect a range of judgments, including liking (R. Reber, Winkielman, & Schwarz, 1998), truth (R. Reber & Schwarz, 1999) and familiarity (Whittlesea, Jacoby, & Girard, 1990; Whittlesea & Williams, 2000).

Perceptual fluency has not been directly manipulated in the context of category learning tasks but there are some studies that point to a role for perceptual fluency in categorization. Oppenheimer and Frank (2008) investigated the effect of perceptual fluency on semantic categorization judgments. When category exemplars (e.g., *pigeon, hummingbird*) were made less fluent 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. This experiment illustrates that perceptual fluency is important for categorization judgments of well learned, semantic categories, but it is not clear whether the same is 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 far from the category boundary, perhaps a coarse-grained 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 result in slower categorization decisions. 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 alternate 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 current study, fluency will be 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, it is expected that manipulations of perceptual fluency will affect categorization. Following a training stage in which participants view category members, participants will complete a test stage in which they judge whether new items are members of the trained category. In this stage, fluency will be 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; Winkielman & Cacioppo, 2001). We expect that items primed with a matching prime should be more likely to be endorsed as category members than items primed with a mismatching prime or no prime because the fluency experienced as a result of the matching prime will be misattributed to the fluency that coincides with category membership.

Method

Participants

Participants included 26 students from the University of Western Ontario who participated in the study either for course credit or for $5. There were 7 males and 19 females with a mean age of 20.20 years (*SE* = 0.71 years).

Materials

The categorization stimuli used in this experiment were similar to the dot patterns that have previously been used to study prototype abstraction (P. J. Reber et al., 1998b; Smith & Minda, 2001; Posner & Keele, 1968). The to-be-learned category was created by first generating a prototype and then probabilistically distorting the prototype to create category members that were similar to the prototype.

To create the prototype, nine points were randomly selected from a 30 x 30 grid and the points were joined to form a polygon. Distortions of the prototype, which formed the to-be-learned category, were created by probabilistically moving each of the nine points of the prototype. Specifically, a series of rings was created around each point in the prototype. The first ring was the single coordinate containing the point itself, the second ring was the eight coordinates surrounding the point, the third ring was the coordinates immediately surrounding the second ring, and so on up to the fifth ring. To distort the prototype, each of the nine points had a probability of .24 of moving to the second ring, .16 of moving to the third ring, .30 of moving to the fourth ring and .30 of moving to the fifth ring. Once the ring that a point would move to was determined, a coordinate within that ring was chosen randomly for the point's new location. This procedure was carried out for each of the nine points in every distortion. 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. 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, non-categorical patterns.

The non-categorical polygons were created to be used in the test phase of the experiment. Each non-categorical polygon was created using the same method as was used to create the category prototype. No distortions were created for any of these polygons. A total of 100 non-categorical 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 non-category members in the test phase.

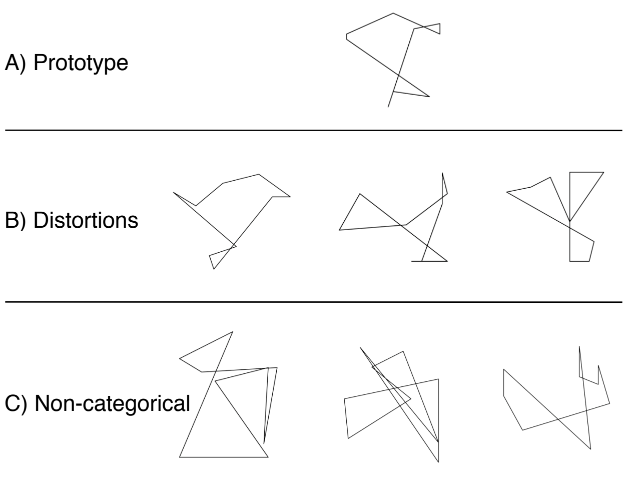

Figure 1: Shape stimuli used in the experiment. A) The prototype for the category. B) Examples of category members that were created by distorting the prototype. C) Examples of unrelated shapes that were not members of the category. These shapes were all randomly generated.

Stimuli were presented using E-prime software (Psychology Software Tools, Pittsburgh, PA) on a PC with a monitor refresh rate of 60 Hz. The prototype was 182 x 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 stimuli appeared at the centre of the screen.

Procedure

The study consisted of a training stage, a test stage and a prime visibility check. In the training stage, participants viewed 40 high distortions of the prototype one at a time on the screen for 5 seconds each. As in prior research, participants were instructed to imagine pointing at the centre of each shape while it was on the screen to ensure that participants attended to the stimuli (Knowlton & Squire, 1993). Following the training stage, participants were told that the shapes they had just seen were members of a single category, in the same way that a series of pictures of dogs would have all belonged to the "dog" category.

Next, in the test stage, 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. Each trial began with a fixation cross followed by a forward mask made of randomly oriented line segments. Next, a prime was presented for 33 ms followed by a backward mask of randomly oriented lines. Finally, the target shape appeared on the screen for 300 ms, at which point participants indicated whether the shape was a member of the category by pushing the "y" key for "Yes" and "n" key for "No". The target shape was followed by a blank screen which remained until the participant made a response. On one third of the trials, the prime was the same as the target shape, on one third of the trials it was a new unrelated shape and on one third of the trials there was no prime (i.e., a blank screen was shown for 33 ms between the masks). The order of the target shapes was randomized for each participant.

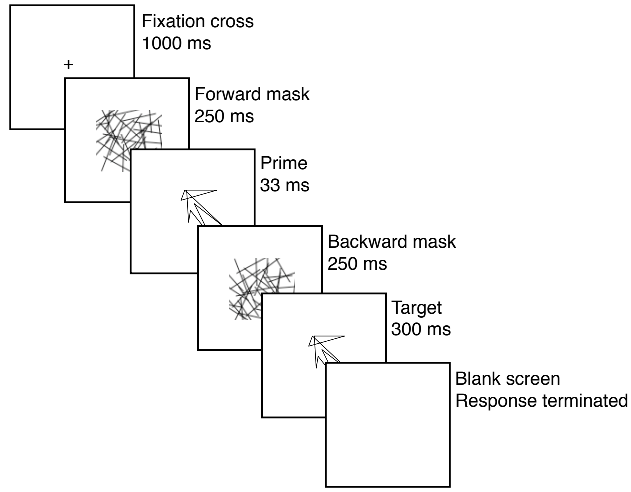

Figure 2: An illustration of the sequence and timing of events during the test stage and prime visibility stage. In the test stage participants categorized the target stimulus. In the prime visibility stage participants indicated whether the prime was the same as the target, different than the target or whether no prime was presented.

The prime visibility stage was exactly the same as the test stage except that participants made judgments about the prime rather than the target shape. In this section, participants were explicitly told about the prime that appeared between the two masks. Their job was to indicate whether the prime was the same as the target shape, different from the target shape or whether no prime was presented by pushing the "s", "d" or "n" buttons, respectively. This stage was included to measure whether participants were able to perceive the primes as they were presented in the test stage.

Results

Prime Visibility

It was important that participants were not able to identify the primes so that any effect of prime type could be attributed to feelings of perceptual fluency rather than explicit identification strategies. We were most interested in whether participants were able to identify the content of the prime rather than the presence of a prime, so we examined whether participants' performance at discriminating between matching and mismatching primes was above chance. Four participants were able to discriminate between matching and mismatching primes so their data was excluded from further analyses. The remaining participants scored an average of 48.75% correct (SE = 1.42%) (chance was 50%).

Categorization Performance

Categorization performance was calculated as proportion of correct responses during the test stage of the experiment. Participants who failed to perform above 50% correct on this stage did not demonstrate that they had abstracted any category knowledge. It was assumed that perceptual learning had not occurred for these participants and perceptual fluency would not be a meaningful cue to category membership. As a result the data from the three participants whose performance was less than 50% on the test phase was excluded from the perceptual fluency analysis. The remaining participants scored an average of 61.93% correct (SE = 1.93%), which is similar to performance in other studies (Knowlton & Squire, 1993; P. J. Reber et al., 1998b, 1998a).

We predicted that regardless of actual category membership, stimuli primed with a matching prime would be more likely to be endorsed as category members than stimuli primed with mismatching prime or when there was 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 non-members. A 2 (Category member vs. Non-member) x 3 (Prime: Match, Mismatch, None) within-subjects ANOVA found that categorization of non-members (M = .69, SE = .04) and members (M = .55, SE = .05) did not differ, $F(1, 18) = 3.41$, $p = .08$. This trend for non-members to be correctly categorized more often than members is likely a reflection of participants' conservative response strategy, where the overall proportion of 'no' responses was .57. There was no difference in performance for stimuli primed by matching primes (M = .59, SE = .05), mismatching primes (M = .64, SE = .04) or no prime (M = .62, SE = .05), $F(2, 36) = 1.86$, $p = .17$. Importantly, as illustrated in Figure 3A, there was an interaction between prime type and category membership, $F(2, 36) = 5.32$, $p = .009$. Tukey's HSD tests were used to investigate the effect of prime type separately for category members and non-members. Contrary to what was predicted, there was no effect of prime type for category members, as the proportion correct for all prime types was the same, all q's < 3, p's $> .10$. However, this was not the case for non-members– prime type did affect proportion correct for non-category members. Specifically, performance for matching primed non-category stimuli was lower than performance for non-category stimuli that were not primed, $q(3, 36) = 4.65$, $p = .006$. Performance on matching primed items was also worse than when a mismatching prime was given $q(3, 36) = 3.72$, $p = .03$, but there was no difference between mismatching primed items and items that were not primed, $q(3, 36) = 0.93$, $p = .79$.

We also predicted that the fluency manipulation would be reflected in the time taken to make a categorization judgment. We considered only correct responses, as is typical of reaction time analyses. We expected that category members that were primed with a matching prime would be categorized more quickly than those not primed, which would be categorized more quickly than those primed with a mismatching prime. As discussed above, for non-members the effect of the prime was to decrease categorization accuracy. Since only correct responses were considered in this analysis, we did not expect to see much, if any, influence of prime type on categorization speed for non-members. For each participant, all responses more than two standard deviations from their average response time were removed and then the average response time for correct responses in each condition was calculated. A 2 (Category member vs. Non-member) x 3 (Prime: Match, Mismatch, None) within-subjects ANOVA was used to investigate the average response time for each condition. Category members (M = 712 ms, SE = 64 ms) and non-members (M = 713 ms, SE = 74 ms) were categorized at the same speed, $F(1, 18) = 0.00$, $p = .99$. There was no difference in reaction time for stimuli primed by matching primes (M = 706 ms, SE = 68 ms), mismatching primes (M = 729 ms, SE = 70 ms) or no prime (M = 702 ms, SE = 65 ms), $F(2, 36) = 0.61$, $p = .55$. Importantly, as illustrated in Figure 3B, there was an interaction between prime type and category membership, $F(2, 36) = 3.78$, $p = .03$. Tukey's HSD tests were used to investigate the effect of prime type separately for category members and non-members. Category members primed with a mismatching prime took longer to categorize than members that were not primed ($q(3, 36) = 3.57$, $p = .04$) but did not take longer than members primed with a matching prime ($q(3, 36) = 2.54$, $p = .19$). Time to categorize category members primed by a matching prime and not primed did not differ, $q(3, 36) = 1.03$, $p = .75$. As expected, mismatching primes slowed the categorization of category members, but the expected speeding by matching primes was not found. Prime type had no effect on categorization time for non-category members, all q's < 2.0, p's $> .40$.

Discussion

We found that categorization judgments were affected by perceptual fluency. When stimuli that were not members of the category were preceded by a matching prime, tendency to incorrectly endorse the stimulus as a category member increased, causing the proportion of correct categorization re-

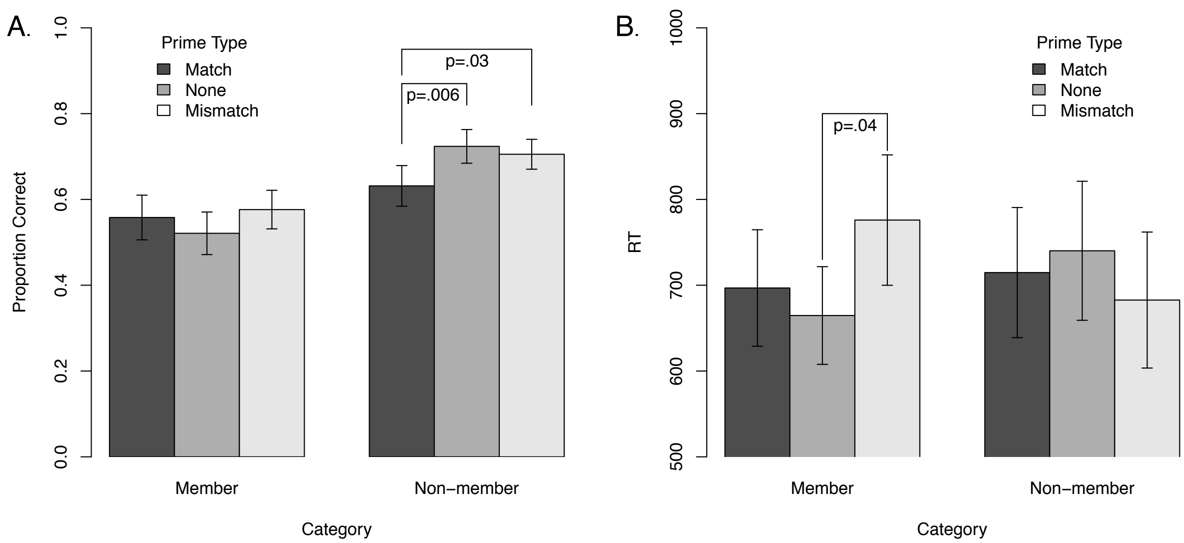

Figure 3: A) Proportion of correct responses for category members and non-members with each type of prime. B) Response time for correct categorization of category members and non-members with each type of prime. Error bars denote standard error.

sponses to decrease. While the proportion of category members correctly endorsed as belonging to the category was unaffected by subliminal priming, the prime type did affect the time taken to categorize category members. Categorization of members was slowed when preceded by a mismatching prime. The prime likely acted as a cue that the item was not a category member, and it took time for participants to reconcile the conflict between the item's true category membership and the prime, slowing categorization.

We initially hypothesized that perceptual fluency would have an opposite effect on categorization accuracy for category members and non-members, but only categorization accuracy of non-members was affected. It is likely that perceptual fluency is one of many cues to category membership, and there is a limit to how much a feeling of fluency can influence a categorization decision. We have suggested that a feeling of perceptual fluency is present for all category members 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.[1] Non-members, on the other hand, 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.

Although the perceptual fluency manipulation was not reflected in categorization performance for category members, it was reflected in response time. Because response time is a continuous measure, it may be more sensitive than the all-or-none categorization decision, allowing it to reflect changes in fluency within category members that were not reflected in categorization accuracy. Indeed, prime type did affect response time for category members such that the categorization decision was slowed by mismatching primes. On the other hand, we did not find that matching primes sped the categorization of members. This supports our hypothesis that category members have reached a fluency threshold. Increases in fluency did not confer any speed advantage but decreases in fluency caused the fluency level to drop below the threshold, resulting in slowed categorization. We also found that primes did not affect the categorization speed of non-members. Recall that matching primes resulted in more incorrect responses for non-members. Because the response time analysis only considered correct responses, the effect of the prime was essentially eliminated for non-members so that no differences in response times were observed.

It is important to note that the effect of the primes is not because participants have adopted explicit response strategies based on the identity of the primes. In the prime visibility stage of the experiment, participants were explicitly instructed to look for the primes and all participants who were able to discriminate between the primes were excluded from all categorization analyses. Therefore, we can be confident that the primes were subliminal and their effect was on feelings of fluency rather than on explicit response strategies.

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

The implications of the current study are 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 this version of the prototype distortion task, but it should not be informative about category membership, as it is in the traditional prototype distortion task (Ashby & Maddox, 2005). In this task, all test items should elicit a feeling of fluency because all items are members of a category. Because the feeling of 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 current study should not affect performance in a task where two categories are learned. However, the fluency manipulation may still affect judgments such as the typicality and attractiveness of the stimulus, which are influenced by perceptual fluency. We are currently carrying out studies to test these predictions.

Conclusion

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

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