The Alliance Between Semantic Memory, Priming, and Episodic Memory

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Abstract

Categorization tasks are often used in priming studies, although the impact of categories has seldom been evaluated. We asked participants to classify natural images of animals belonging to four different categories. These were bovid, cats, rodents, and monkeys. The study consisted of three parts: learning, testing, and recognition. Participants responded faster during testing than learning, but this effect was mainly found in one category: rodents. At recognition, rodent target images resulted in a higher correct recognition rate than the other categories. These results suggest that prior semantic knowledge influences behavioral priming and priming influences formation of episodic memory.

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1. Introduction

Categorization is a very spontaneous and often automatically operating process in our everyday lives. In order to process new information quickly, objects are often mainly encoded regarding their category-specific properties. This categorization process underlies a wide range of priming tasks, like naming or living/artificial classifications. Recent work showed that categorization happens in most, if not all, memory systems (Smith & Grossman, 2008). Prior semantic knowledge about categories might interact with behavioral priming in different ways, which have not been investigated so far. Priming can be defined as the facilitation of a response to a stimulus from one presentation to the next (Tulving, Schacter, & Stark, 1982). Perceptual priming describes the repeated exposure to the same stimulus while conceptual priming describes effects of exposure of similar stimuli. The behavioral measurements are mostly response times, accuracy, and sometimes fragmentation levels. Many priming studies present their stimuli only for a very short duration and combine these stimuli with a mentally engaging two-choice classification task (e.g., Greene & Oliva, 2009; Horner & Henson, 2012).

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Our study had two main goals. One aim was to develop a method that allows the investigation of perceptual priming while still mimicking natural visual perception conditions. It is not very often that we perceive objects only for a brief few milliseconds. More often, it happens that we do not attend to every detail in our surroundings because we focus on details relevant to the situation by filtering these out of the multitude of information that is perceived simultaneously. Furthermore, we decided to use natural stimuli and present these in color to gain better insight into real-life visual perception underlying visual priming processes (Bar, 2004). The second aim of this study was to investigate the influence that similar but still distinguishable categories have on the priming process. A difficult task that combines a wide range of conceptual similar stimuli should be sufficient to suppress conscious processing of stimulus-specific details and thus, allow us to investigate priming in a more natural setting.

2. Method and materials

2.1. Participants

Behavioral data was obtained from 25 healthy undergraduate and graduate students (6 male, 19 female) who participated without any deeper knowledge of the true nature of the study. All participants were native German speakers and they received course credit points for their time. All students had normal to corrected-to-normal vision and ranged between 19 and 33 years ($M = 23.6, SD = 3.75$). There were no reported psychological or psychiatric disorders prior to the study and all participants signed a written form of consent.

2.2. Materials

The visual stimuli consisted of 200 colored photos equally distributed across four animal categories. These were bovid, cat, rodent, and monkey. Photos were mostly collected from the web and were published in the public domain. All depicted animals were photographed in the wild, showing them in different positions, angles, and in different environments (see also Fig. 1). For the priming tests each animal category was divided into five different species, e.g., the category “cat” consisted of seven pictures each from cheetah, lion, manul, cougar, and ocelot. One picture of each species was only used during practice; the other six were randomly distributed across the other three parts (see 2.3 Procedure). During the recognition test at the end of the study further photos from previously unseen species from the same categories were presented, e.g. in the category “cat” photos from jaguars and snow leopards were shown. Prior to the study, we conducted a pre-study to ensure that only photos were used in the study whose category affiliation was of a medium difficulty. All photos were normalized for each category in terms of color intensity, brightness, and pixel size (1024x768) using the program Matlab (7.7.0.471 R2008b).

2.3. Procedure

The study consisted of a practice and three main parts; a learning and a testing part with the same underlying task, and a recognition part (see Fig. 1). During learning and testing the task was to categorize animal photos in terms of their category affiliation: bovid, cat, rodent, and monkey.

At the beginning of the study, participants were informed that first they will complete two short practice runs to familiarize themselves with the task which was followed by three longer parts. During the first practice run, stimuli and categories were shown together on the screen. The words for the categories were presented in different colors that corresponded to the subsequent colors on the four response keys on the keyboard. During the second run the stimuli were presented without the help of the categories. Participants received positive or negative feedback during both runs. The stimuli that were used during practice were not presented again later in the experiment, instead we presented animals representing the same category.
Participants were asked to respond as fast and as accurate as possible throughout the experiment. The procedure of the learning and testing parts was similar to the second practice run. Stimuli were presented for as long as it took participants to classify them to one of the four categories. No fixation cross was presented between stimuli. During the learning part 80 images – equally distributed across the categories and species – were presented randomly. After this first learning part a short reminder was presented on the screen, again showing the four categories in the subsequent colors. This pause allowed a short rest for the participants if necessary. During the testing part 40 images from the learning part were presented randomly with 40 new ones, again equally distributed across categories and species. The measures were the differences of the reaction times from learning to testing, with priming effects attributed to lower latencies. Beforehand, participants were not informed that some images would be presented repeatedly.

After a brief pause, participants continued with the recognition part. Here, every image that was used during the parts learning and testing was randomly presented with 40 new ones. This time participants were asked to sort the pictures according to when they had seen them previously. For example, for target images that were repeatedly presented in the parts learning and testing the response should have been ‘Test 1 & Test 2’, which was renamed to ‘Learning & Test’ during the analysis. Thus, participant responses during recognition (‘Test 1 & Test 2’ / ‘Test 1’ / ‘Test 2’ / ‘New’) were classified in terms of how the stimuli were presented: learning, testing, learning & testing, or unknown. For this decision participants had as much time as they needed and were not asked to speed up their responses.

Overall, participants classified 80 novel images together with 40 targets during learning and testing. These 120 images were then combined with an additional 40 for the recognition section. All 160 stimuli that were presented in the three parts (learning, testing, & recognition) were randomized anew for each participant to counterbalance for differences in difficulty between photos within each species.

The program Presentation Version 14.2 (Neurobehavioral Systems) was used to program the experiment and run the study.

3. Results

3.1. Behavioral results of learning and testing

Across the data for the parts learning and testing, only 74 trials were discarded because participants responded to the stimuli with a wrong category. In addition, trials with a reaction time (RT) lower than 200 ms or two standard deviations above a participant’s mean for a given part, condition, and category, were excluded from further analyses (249 trials). Thus, the main variable constituted from RTs of 3689 correct trials (92%) of all data from learning and testing.

A first look at a difference between learning and testing regarding the development of the RTs for targets and novels, respectively, showed that participants indeed increased their reaction time across the two parts (see Figure 1 for RT difference between the two parts). A repeated-measures ANOVA revealed a statistically significant effect for the interaction between category and part [$F(2.24, 53.81) = 3.83, p = .023, \eta^2_p = 1.39$], between categories [$F(2.03, 48.75) = 4.44, p < .016, \eta^2_p = .156$] and between parts [$F(1, 24) = 10.84, p = .003, \eta^2_p = .311$].

Importantly, these significant effects can be backtracked mainly to the category of the rodents for stimuli groups, targets and novels. A paired t-test revealed only for rodent stimuli statistically significant decrease between learning-novel ($M = 992.46, SD = 233.17$) and testing-novel ($M = 883.42, SD = 136.28$; $t(24) = 2.733, p = .012$) as well as between primes (learning, $M = 1089.72, SD = 355.03$) and targets (testing, $M = 888.82, SD = 152.43$; $t(24) = 4.157, \ p < .001$). None of the other combinations led to statistically significant results.
3.2. Recognition part

At recognition, participants recognized more new images correctly than targets or novels from the parts learning and testing. A two-way within subjects ANOVA revealed a statistically significant interaction effect between learning/testing part and categories \(F(9, 384) = 3.394, p = .001, \eta^2_p = .074\). Table 1 shows that this effect results from a statistically significant higher amount of correct classification of target stimuli of the rodent category \(F(3, 384) = 202.42, p < .01, \eta^2_p = .613\).

Table 1. Correct classification of the stimuli from Learning and Test part for targets, learning-novels, test-novels, and unknowns, for each category separately. Mean amount and standard deviations (M(SD)) are included, the maxima for each category and condition were 10.

| Category   | Targets | Learning-novels | Testing-novels | Unknowns |
|------------|---------|-----------------|----------------|----------|
| Bovid      | 3.2 (2) | 2 (1.9)         | 1.4 (1.4)      | 8.1 (2.5) |
| Cats       | 2.8 (2.1)| 1.4 (1.5)       | 2.2 (1.5)      | 8.4 (3)  |
| Rodents    | 4.7 (2.2)| 1 (1.4)         | 2.4 (1.9)      | 7 (2.8)  |
| Monkeys    | 2.6 (1.9)| 1.4 (1.6)       | 2.6 (1.9)      | 8.5 (2.7) |

Additionally, further analyses showed that participants did respond to most stimuli with the answer ‘unknowns’ (‘learning & test’ = 11.7%, ‘learning’ = 18.8%, ‘test’ = 19.7%, ‘unknowns’ = 49.7%). But no significant correlation was found between correct recognition of stimuli and their prior priming from learning to test.

4. Discussion

We developed a difficult classification task with four animal categories to engage participants’ attention on the task and not on encoding the stimuli. Our insignificant results in the recognition part support the hypothesis that participants did indeed not learn the stimuli. Surprisingly, we could not show similar effects for all four categories. Instead, priming seems to be more pronounced for more unfamiliar stimuli like rodents than for bovid, cats, or monkeys. Even though, no significant results were found when correlating higher priming effects with better recognition rates, the rodent category also elicited the best classification rate in the recognition part. This might be an indicator that priming supports the formation of episodic memories of unfamiliar images.

Our results suggest that priming is strongly influenced by prior semantic knowledge. Facilitation of responses was only found for the category rodents. This is in concord with results from Soldan and colleagues (2008) who reported similar behavioral priming for familiar and unfamiliar objects but different neural responses in the brain. But in contrast to Soldan et al., who used artificial drawings of real-world and novel objects, we used real-world photos. In general, participants seemed to respond to our photos faster than it might have been the case with drawings, thus producing a ceiling effect for the more familiar images of bovid, cat, and monkey. In order to avoid that any stimuli elicit negative emotional responses, we used several unknown rodent species for Europeans, like photos of the South-American Capybara. It would be of interest to investigate if our results also reflect on brain activation similar to the findings of Soldan and colleagues.

Studies demonstrated that humans are capable of memorizing a huge amount of objects and scenes (Brady, Konkle, Alvarez, & Oliva, 2008; Konkle, Brady, Alvarez, & Oliva, 2010). Even though, most priming studies do not control for conscious encoding by implementation of a recognition task but analyze and interpret priming solely on the improvement of participants’ response. Our results from the recognition part suggest two points. One, for the most part participants did not consciously learn the stimuli. Thus, we can assume that the combination of similar categories and more demanding classification tasks indeed prohibited conscious encoding. The second result shows that a higher amount of correct recognitions of rodent targets did not correlate with the corresponding priming of these particular stimuli. It might be that unfamiliar stimuli in general are processed in more detail resulting in better episodic recognition without resulting in behavioral priming per se. Here, it also
would be of interest to investigate the neural response during these recognition processes to gain a better understanding of the differences between familiar and unfamiliar and episodic and false recognitions.

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