Memory is Deceiving: a Typical Size Induces the Judgment Bias in the Ebbinghaus Illusion

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Abstract

Grounded cognition theories state that conceptual knowledge is closely linked to the current situation and embodied in sensory dimensions. Alongside the interaction with the environment, knowledge related to our environment is continually recovered from memory. Thus, the perceptual situation is closely linked to the reactivated traces in memory. Visual illusions correspond to a situation in which the perceived image differs from the objective image. In order to explore the link between conceptual processes and perceptual processes, we used the Ebbinghaus illusion and replaced the perceptual size difference of the inducers by a typical size difference simulated in memory (animals with a typically large or small size were used as inducers). Results showed a bias in judgments of the size of the test elements even when the inducers did not have different physical sizes but only reactivated different sizes in memory.

Keywords: Embodied cognition; Simulation; Visual illusion; Memory; Perception

Introduction

A fascinating phenomenon in psychology, referred to as the "contrast effect" (Von Helmholtz, 1866), can be illustrated by the following example: individuals tend to perceive a person as being smaller when he or she is standing in front of a large building (Smith, 1728). Similarly, a sports announcer looks shorter when surrounded by a team of basketball players but taller when interviewing racehorse jockeys. The contrast effect is observed in some optical illusions. In the Ebbinghaus illusion, the magnitude of the contrast effect varies as a function of the physical similarity (Coren & Miller, 1974) and the conceptual similarity (Coren & Enns, 1993) between the test element and the inducers (surrounding elements). Illusions can be generated by inappropriate or misapplied knowledge (Gregory, 1997). Individuals construct conceptual knowledge throughout their lives through their interactions with the environment. That is why Binet (1895) used age as a predictor of sensitivity to visual illusion and made the assumption that young children and adults would not react in the same way to the contrast effect illusion. He demonstrated that bias in the Müller-Lyer illusion declines with age, with young children being more susceptible to the illusion than adults (see also Wohlwill, 1960; Predebon, 1985). However, in these studies, knowledge appears as a broad and undefined notion.

In grounded and embodied cognition theories, conceptual knowledge involves the activation of sensorimotor properties and is grounded in simulations of actual interactions with the environment (Barsalou, 2005; Wu & Barsalou, 2009; Meteyard, Bahrami, & Vigliocco, 2007) . The simulators consist of the common neuronal patterns that are activated during the perceptual processing of an object (Barsalou, 2003). Thus, the processing of an object implies the reactivation in memory of all the sensorial properties that are associated with this object (Versace et al., in press). The simulation is contextual and occurs in the same areas that are involved in perception (Slotnick & Schacter, 2006; Simmons, Hamann, Harenski, Hu, & Barsalou, 2008). Many behavioral studies have shown that knowledge is based on the activation of sensorimotor components and involves the simulation of concepts. The simulation can relate to, for instance, the color (Goldstone, 1995), the shape (Zwaan & Yaxley, 2004) or the size of objects (Solomon & Barsalou, 2004). According to this framework, conceptual knowledge can influence perceptual tasks. For instance, the simulation of typical size influences judgments in a categorization task (Ferrier, Staudt, Reilhac, Jiménez, & Brouillet, 2007) and visual search are affected by typical size in memory (Riou, Lesourd, Brunel, & Versace, 2011).

One frequently studied size contrast effect is the Ebbinghaus illusion. In this illusion, the difference in size perception between two identical test circles is induced by the size of surrounding circles. Individuals perceive a difference even if there is no perceptual difference in the size of the test circles (inner circles). In the best-known version of this illusion, two test circles of identical size are placed close to each other. Large inducers (surrounding circles) surround one of these test circles, while small inducers surround the other test circle. The small or large size of the inducers generates a bias in the perceptual judgment of the size of the test circles. Thus, the test circle surrounded by large inducers appears smaller than the other and, conversely, the test circle surrounded by small inducers appears larger.

Using the Ebbinghaus illusion, Rey, Riou, and Versace (in press) manipulated the presence or absence of a difference in inducer size. In a first experiment, the inducers were physically different in size (as in the best-know version of the illusion). In a second experiment, the inducers were physically identical in size but were presented in different colors (blue or red). A color-size association was created in a first phase in which the participants had to categorize the circles according to their color. In this phase, the red were large and the blue circles were small (the association was counterbalanced across participants). Thus, in a test phase, the red inducers reactivated a large size in memory and the blue inducers reactivated a small size, even if the inducers had the same physical size. In both experiments, the participants had to judge whether the test circles were identical or different in size. The stimuli were designed in a way that either enhanced or diminished the perceptual bias. The results revealed similar effects in the two experiments, i.e. slower RTs and a higher correct response rate were observed when the stimuli induced an enhanced bias than when they induced a diminished bias. The reactivation of the size previously associated with the colors induced a bias in the perceptual judgment of size. A perceptually absent size (reactivated size) can therefore influence the judgment of the size of different stimuli.

In line with this study, the present research assesses the following assumption: the simulation of a typical size should induce a contrast effect between the test circles in the same way as the perceptually present size in the Ebbinghaus illusion. Rather than using an association to reactivate a size in memory, the present experiment was designed to use a typical size already present in memory (i.e., by using items that had been already be associated with a size in memory by the individuals themselves during their past experiences). The inducers all had the same physical size and were replaced by photographs of typically large or typically small animals. The test circles could be identical or different in size. The participants had to categorize these test circles as identical or different. Two main assumptions were formulated. First, when the test circles are the same size (identical condition), participants should be tempted to categorize them as different since the classical configuration of the Ebbinghaus illusion induces a difference between them. Consequently, participants should take longer to respond when the test circles are identical than when they are different. Second, when the test circles differ in size, the bias engendered by the contrast effect should increase (enhance condition) or decrease (decrease condition). Consequently, participants should respond faster and more acurrately when the configuration of the stimuli induces an increase in the magnitude of the illusion (enhance condition) than when it leads to a reduction in the magnitude of this illusion (decrease condition).

Method

Participants

Twenty participants volunteered to take part in the experiment (16 women, *M*age= 22.13 *SD*age= 3.40). All of them had normal or corrected-to-normal vision and were native French speakers.

Stimuli and material Each stimulus was composed of a right part with a test circle and six inducers and a left part with another test circle and other inducers.

Inducers. Eight gray-scale photographs of animals were selected: four animals with a typically large size (an elephant, a hippopotamus, a bear and a rhinoceros, i.e. taller than 100 cm) and four animals with a typically small size (a rabbit, a squirrel, a mouse and a hamster, i.e. smaller than 10 cm). The items may be found in Appendix. These large or small animals acted as the inducers. In each stimulus, the inducers consisted of one of the large animals (e.g., six circles with an elephant in the right section) and one of the small animals (e.g., six circles with a rabbit in the left section). All the inducers had the same diameter (1.5 cm). Each large animal was presented together with each small animal, giving a total of 32 combinations (16 combinations with the large animals on the left and the small animals on the right and 16 combinations with the opposite configuration). All the pictures had the same format (386 $\times$ 260 pixels with a resolution of 72 $\times$ 72 dots per inch).

Test circles and conditions. The stimuli also contained two test circles which were either identical in size with a diameter of 1.5 cm ("identical" condition) or different in size with a diameter of 1.2 cm or 1.8 cm ("enhance" and "decrease" conditions). Three conditions were created and are depicted in Figure 1. The configuration of the stimuli in which the size of the test circles was identical corresponded to the "identical condition" (Figure 1a). In this condition, the distance between the test circle and the inducers was 0.8 cm. The configurations in which the test circles differed in size corresponded to the other two conditions in which the effect was enhanced or decreased. For the stimuli in the "enhance condition", the smaller test circle was surrounded by the large inducers, and the larger test circle was surrounded by the small inducers, a configuration which should increase the perceived size difference (Figure 1b). In the "decrease condition", the smaller test circle was surrounded by the small animals, and the larger test circle was surrounded by the large animals, a configuration which should decrease the perceived size difference (Figure 1c). In the enhance and decrease conditions, the distance between the small test circle and the inducers was 1.1 cm, and the distance between the large test circle and the inducers was 0.5 cm.

Procedure and design The experiment was conducted on a Macintosh IMac. PsyScope software X B57 (Cohen, MacWhinney, Flatt, & Provost, 1993) was used to set up and manage the experiment and each participant was tested individually during a session that lasted approximately 10 minutes. After seeing a fixation point presented for 500 ms, the participants had to judge as quickly and accurately as possible whether the sizes of the two test circles were identical or different. They indicated their choice by pressing the appropriate key (the key "a" or "p" on the French keyboard) and the order of the keys was counterbalanced. The stimuli were presented for 500 ms with an inter-trial interval of 1500 ms. The "identical" stimuli were presented 48 times and the "enhance" and "decrease" stimuli were presented 24 times each.

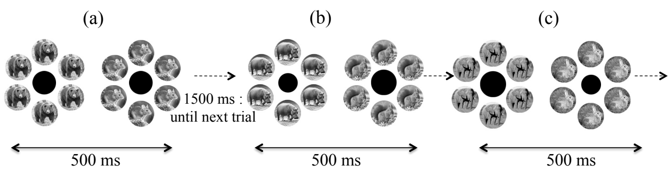

Figure 1: Illustration of the experimental protocol with one set of the stimuli for the (a) identical condition, (b) enhance condition, (c) decrease condition.

Results

Mean correct response latencies and error rates were calculated across participants for each experimental condition. Latencies that differed by more than 3 standard deviations from the individual means in each condition were discarded (less than 5% of the data). Separate analyses of variance were performed on the latencies and percentages of correct responses. The data analyses were performed using STATISTICA (version 8.0, StatSoft, Inc.).

A first analysis of variance (ANOVA) performed with subjects as random variables and Test circle size (the comparison between the responses for the "identical" and "different" stimuli) as within-subjects factor revealed no significant effect on the error rates, $F(1,19) = 1.32$ (identical condition: M = 7.49; SE = 1.87; different condition: M = 9.81; SE = 1.19). However, the analysis of latencies showed that the participants took significantly longer to categorize the "identical" stimuli (M = 699 ms; SE = 15) than the "different" stimuli (M = 670 ms; SE = 12), $F(1,19) = 4.93$, $p < .05$, $\eta_p^2 = .21$. The perceptual size of the inducers created a bias in the perception of the size of the test circles, with the result that the participants took longer to identify the identical test circles in the identical condition.

A second ANOVA was performed with subjects as random variables and Manipulation of illusion (enhance and decrease conditions) as within-subjects factor. The analyses performed on the error rates revealed that the participants made more errors in the "decrease" condition (error rate of 11.88%) than in the "enhance" condition (8.53%), $F(1,19) = 6.19$, $p < .05$, $\eta_p^2 = 0.25$. Moreover, analyses of latencies indicated that the participants were faster in the "enhance" (654 ms) than in the "decrease" condition (692 ms), $F(1, 19) = 21.01$, $p < .001$, $\eta_p^2 = 0.53$.

A signal detection measure (d's) for each experimental condition was calculated. The d's indicate the strength of the signal relative to the noise. A "different" response given in the "enhance" or "decrease" condition (i.e. a correct response when the test circles were different) corresponded to a hit. A "different" response given in the "identical" condition (i.e. an error when the test circles were identical) corresponded to a false alarm. Consequently, the same false alarm rate was used in the "enhance" and the "decrease" conditions assuming constant bias between conditions. The d's were subjected to an ANOVA with Manipulation of illusion (enhance vs. decrease) as within-subject factor. A significant main effect was observed, with it being easier for the participants to perceive a difference in the enhance condition (d' = 2.91) than in the decrease condition (d' = 2.76), $F(1,19) = 5.05$, $p < .05$, $\eta_p^2 = .21$. The perception of the difference was influenced by the typical size of the inducers.

Discussion

The aim of the present study was to demonstrate that a simulated dimension in memory constructs across past experiences can influence a perceptual judgment. Using a paradigm based on the Ebbinghaus illusion, this study shows that the perceptual judgment of size can be influenced by the reactivation of a size in memory. In the experiment, the participants had to categorize two test circles as identical or different based on their size. Six inducers surrounded each test circle. The inducers consisted of six circles (of the same physical size) containing pictures of animals with a typically large size or a typically small size. The test circles were either of the same size (identical condition) or a different size in order to magnify (enhance condition) or diminish (decrease condition) the bias created by the illusion. The results showed that 1) the participants were slower to categorize the identical stimuli than the different stimuli and 2) the participants categorized the stimuli more quickly and easily in the enhance condition than in the decrease condition. These results indicate that when the test circles were identical in size, the simulation of the inducers' typical size modified their perception. A possible explanation could be that the participants were tempted to categorize the circles as different because of the contrast effect resulting from the large and small simulated size of the inducers (as in the classic version of the Ebbinghaus illusion due to the large or small perceptual size of the inducers). The results also showed that when the participants had to categorize the test circles as different, the RTs were faster in the enhance condition than in the decrease condition. Furthermore, besides being faster, the participants also found it easier to perceive the difference between the test circles in the enhance condition than in the decrease condition.

This finding lends support to the assumption that the bias was magnified in the enhance condition and reduced in the decrease condition.

When the test circles were different, it is difficult to explain the observed results in terms of a semantic effect of size congruence between the inducers and the test circle. Indeed, a semantic effect should have induced faster RTs in the decrease condition (e.g., congruence between the small size of the test circles and the size of the small animal) than in the enhance condition (e.g., incongruence between the small size of the test circle and the size of the large animals). However, the opposite effect was observed.

Perceptual simulation occurs in conceptual processing (Goldstone & Barsalou, 1998). When individuals represent an object, they simulate past experiences of it (Barsalou, Pecher, Zeelenberg, Simmons, & Hamann, 2005). The simulation occurs in the same brain areas as perception (e.g., Slotnick & Schacter, 2006). The simulations correspond to multimodal representations of a concept. All the relevant sensory dimensions, such as size, are simulated during the confrontation of the concept. In the present study, the typical size of the animals was simulated and this size reactivated in memory by simulation induced a perceptual bias in the categorization task of the test circles' size. Thus, a simulated dimension can replace a perceptual dimension. This supports a grounded cognition perspective in which knowledge is closely linked to the current situation and derives from the reactivation of traces of past experiences in memory.

The magnitude of the bias is partially dependent on the size of the inducers (Massaro & Anderson, 1971). Consequently, we should be able to modulate the bias by manipulating the typical size of the inducers. A smaller difference between the typically large and typically small inducers should reduce the perceptual bias. Conversely, a larger difference should make it easier to detect a difference between the two test circles. Further studies could explore this hypothesis by using psychophysics measures to explore the magnitude of the perceptual bias induced by the simulated size of the inducers.

Acknowledgments

This research was supported by a graduate research allocation from the French Ministry for Higher Education and Scientific Research.

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Appendix

Illustration of the small animals: (a) a rabbit, (b) a mouse, (c) a hamster, (d) a squirrel; and the large animals (e) a hippopotamus, (f) an elephant, (g) a bear, and (h) a rhinoceros in the identical condition.