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Memory plays tricks on me: Perceptual bias induced by memory reactivated size in Ebbinghaus illusion

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ABSTRACT

The relationship between perceptual and memory processing is at the core of cognition. Growing evidence suggests reciprocal influences between them so that memory features should lead to an actual perceptual bias. In the present study, we investigate the reciprocal influence of perceptual and memory processing by further adapting the Ebbinghaus illusion and tested it in a psychophysical design. In a 2AFC (two-alternative forced choice) paradigm, the perceptual bias in the Ebbinghaus illusion was induced by a physical size (Experiment 1) or a memory reactivated size of the inducers (Experiment 2, the size was reactivated thanks to a color–size association). One test disk was presented on the left of the screen and was surrounded by six inducers with a large or small (perceptual or reactivated) size. The test disk varied in size and participants were asked to indicate whether this test disk was smaller or larger than a reference disk presented on the right of the screen (the reference disk was invariant in size). Participants' responses were influenced by the size of the inducers for the perceptual and the reactivated size of the inducers. These results provide new evidence for the influence of memory on perception in a psychophysics paradigm.

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1. Introduction

The relationship between perceptual and memory processing is at the core of cognition. It is commonly accepted that perception could serve as input to memory processing (Locke, 1960/1975; Prinz, 2002) and it has been claimed that visual perception is insulated against cognitive processing (Pylyshyn, 1999, 2003; Firestone, 2013). Based on the fact that knowing about perceptual illusions does not make them disappear, Pylyshyn (1999) proposed that they represent "a very clear separation between what you see and what you know is actually there". However, direct influences of memory processes biasing perception have been observed (Bruner, 1957; Gregory, 1997; Goldstone, 1995; Hansen, Olkonnen, Walter, & Gegenfurtner, 2006) and a growing number of studies investigated the interactive nature of memory and perceptual processes (for a review see Goldstone, de Leeuw, & Landy, 2015). Embodiment theories accounted for reciprocal influences between perceptual and memory processing in terms of symmetrical processes, i.e. the sharing of common processes (Barsalou, 1999, 2008). Indeed, memory processes are supposed to be grounded in the same sensory-motor systems as those used in perceptual processes (e.g., Glenberg, 1997; Pecher & Zwaan, 2005; Collins & Olson, 2014). Using a paradigm based on the Ebbinghaus illusion (a perceptual illusion), the present study aims to investigate the symmetry of memory and perceptual processing using psychophysics.

The demonstration of symmetrical processes suggests that memory features bias perception of participants just as the reverse influence of perceptual features bias memory processing (see van Dantzig, Pecher, Zeelenberg, & Barsalou, 2008). The study of size appears a good choice because the perception of size is not just influenced by physical characteristics. Indeed, several studies have found that memory knowledge about size and perception of a physical size are inter-related (Paivio, 1975; Banks & Flora, 1977; Besner & Colheart, 1979; Dehaene, 1992; Henik & Tzelgov, 1982; Schwarz & Heinze, 1998; Tzelgov, Meyer, & Henik, 1992). For instance, memories of the typical size of animals interfere with judgments about the font size of words referring to these animals. Rubinstein and Henik (2002) observed congruency and interference effects by varying the font size of the name of usually small or large animals (e.g., "ant" vs. "lion") in a Stroop-like paradigm: ant vs. lion — congruent and ant vs. lion — incongruent. The same kind of influence between perceptual and memory processing of magnitude was observed for numbers. Firestone (2013) investigated the influence of conceptual size in memory on numerical processing in a parity judgment task. Participants saw pictures of large or small animals with the same physical size as primes and then viewed a large or a small integer number as target (from 1 to 9). RTs were faster for the congruent condition (e.g., when the picture of a small animal was presented before a small number) than the incongruent condition. Not only do memory features influence perceptual judgment, but these two

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processes appear to interact together in real time. Riou, Lesourd, Brunel, and Versace (2011) demonstrated that the memory size of an object (e.g., a plane has a large size whereas a clock has a small one) influences the detection of a perceptual difference. In a visual search paradigm, participants were faster to detect a difference when there was both perceptual and memory differences between the target and other objects. Consequently, the computation of a perceptual size difference between two or more objects is influenced by the memory size of these objects.

These inter-influences of memory and perceptual processing suggest that similar effects should be observed regardless of the presence/absence of the manipulated features (e.g., Rey, Riou, Cherdieu, & Versace, 2014; Riou, Rey, Cuny, & Versace, in press). For instance, Rey, Riou, and Versace (2014a) used the well-known Ebbinghaus illusion in which the difference in the physical size of several surrounding disks induces a perceptual bias in the test disks' size. They manipulated the presence or the absence of a difference in the size of the inducers in the Ebbinghaus illusion. As in the traditional version of the illusion, the inducers were physically different in size in the first experiment. 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 previous phase, for instance the red disks were large and the blue disks were small. In the test phase, the red inducers thus 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 disks 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 with slower RTs and higher correct response rates observed when the stimuli induced an enhanced bias compared to 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 reactivated size influenced the judgment of the size of different stimuli as a perceptually size does. This result was also observed by using a more ecological association between pictures and memory size that is large animals or small animals (Rey, Riou & Versace, 2014b). Beyond a mutual interaction (see Riou et al., 2011), perceptual and memory processes appear to induce similar effects. This demonstration of similar effects regardless of the presence/absence of the components activated by the task supports the hypothesis of symmetry between perceptual and memory processing.

Nonetheless, one possible limitation of the latter studies is that only RTs and correct response rates were recorded. This choice of dependent variables does not enable one to draw conclusions about the origin or nature of the effect which might arise from a decision or a perceptual bias. In perception, psychophysics is commonly used to study the effect of the variation of a perceptual stimulation on the subject's experience (Bruce, Green, & Georgeson, 1996). Consequently, psychophysics offers the tools to assess the possible perceptual bias caused by perceptual and memory manipulation in addition to the magnitude of the effect. In line with the current body of literature, we use a methodology as close as possible to the methods used to study early-stage perceptual processing.

The aim of this study was to further investigate the symmetry between memory and perceptual processing by exploring the possible perceptual nature of the apparently symmetrical effect. The study consisted of two experiments using a 2AFC (two-alternative forced choice) paradigm in which the perceptual bias in Ebbinghaus illusion was induced either by the physical size (Experiment 1) or by the memory size of the inducers (Experiment 2, the size was reactivated thanks to a previous color–size association) and measured in a psychophysical paradigm. A test disk was presented on the left of the screen and was surrounded by six inducers with a large or small (Exp. 1: physical or Exp. 2: reactivated) size. This disk varied in size and participants were asked to indicate whether it was smaller or larger than a reference disk presented on the right of the screen (the reference disk was invariant in size). We expected that the point of subjective size equality (PSE) would vary according to the size of the inducers irrespective of whether the inducers size is physically present or reactivated. For instance, large inducers should lead participants to perceive a test disk as smaller than a reference disk that has the same physical size as the test disk.

2. Experiment 1: perceptual size of the inducers

2.1. Method

2.1.1. Participants

Eighteen participants volunteered to take part in the experiment, all of whom completed a written consent form before the experimental session commenced. They were all students at the University of Lyon 2 and had normal or corrected-to-normal vision.

2.1.2. Stimuli and material

Stimuli were based on the Ebbinghaus illusion paradigm. Although the original configuration of the Ebbinghaus illusion consists of the simultaneous presentation of two test disks, one surrounded by large inducers and another by small inducers, several studies used only one test disk surrounded either by large or small inducers (e.g., Rose & Bressan, 2002; Coren & Enns, 1993). We used this common procedure in presenting one black test disk surrounded by either large or small inducers on the left of the screen and a black reference disk on the right of the screen with a diameter of 1.322°. The size of the test disk varied from the reference disk size by steps of 0.022° from 1.146° to 1.498 for a total of 16 test disks (no test disk had a diameter equal to that of the reference disk). Disks 1 to 8 were smaller than the reference disk and the disks 9 to 16 were larger than the reference disk. The test disk was surrounded either by six small or six large disks of the same size called the inducer disks (six inducers were used because they can be expected to enhance the perceptual bias, see Massaro & Anderson, 1971). Each large and small inducer had diameters of 1.939° and 0.705° respectively (see Fig. 1).

2.1.3. Procedure and design

The experiment was performed on a 21.5-inch Apple IMac. OpenSesame 0.27.4 (Mathot, Schreij, & Theeuwes, 2012) was used to set up and to manage the experiment. Each participant was tested individually during a session that lasted approximately 20 min. Stimuli were viewed from an approximately 65 cm distance. After seeing a fixation point presented for 500 ms, participants were asked to indicate as quickly and accurately as possible whether the test disk was larger or smaller than the reference disk. They indicated their choice by pressing the appropriate key on a keyboard. Responses were all given with the right hand. Participants used their forefinger for the “smaller” response (key “b”) and they used their middle finger for the “larger” responses (key “h”). This configuration of keys was selected to create a link between a “larger” response and an up key, and conversely, between a “smaller” response and a bottom key. The link between responses and keys increases the motor fluency and avoids an incompatibility effect that would interfere with some responses (see for instance the Stimulus Response Compatibility, Tucker & Ellis, 1998). The stimuli, both the test disk with its inducers and the reference disk, were presented up until the subject's response. Two trials were separated by an inter-trial interval of 1500 ms. Each of the sixteen test disk sizes were presented twelve times with the large inducers and twelve times with the small inducers in a random order for a total of 384 trials (16 disks × 12 presentations × 2 2 types of inducers).

2.1.4. Statistical analyses

Initial data processing and subsequent analyses were performed using R version 3.1.0 (R Foundation for Statistical Computing). Raw responses were converted into proportions of ‘test larger than reference’ responses per participant and per condition (see Fig. 2). These data were then fitted locally using the modelfree package (Zychaluk &