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Priming and implicit recognition depend on similar temporal changes in perceptual representations

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Previous studies have reported that longer stimulus presentation decreases the magnitude of priming. In the present study, we used meaningless kaleidoscope images, which were reported to minimize conceptual processing, to investigate the mechanism of the phenomenon. We assessed the impact of stimulus duration on perceptual priming (Experiment 1) and implicit recognition memory (Experiment 2). Both the magnitude of priming and the accuracy of implicit recognition were lower with the longer stimulus presentation (350 ms) compared with the shorter presentation (250 ms). This coincidence of temporal dynamics between priming and implicit recognition suggests similar underlying memory mechanisms. In both cases, the decrease of performance with longer presentation can be explained by either changes in perceptual processes or interference from explicit memory retrieval.

1. Introduction

1.1. "Rise and fall" pattern of priming

Priming refers to the retrieval of pre-acquired representations without a need for conscious awareness of memory (Graf & Schacter, 1985). Furthermore, the magnitude of priming is often assessed by behavioral measures such as faster response time or greater accuracy. Several studies suggest that short presentation of a previous stimulus provides positive priming, whereas longer presentation leads to weaker or even negative priming (Barbot & Kouider, 2012; Faivre & Kouider, 2011; Huber & O'Reilly, 2003; Zago, Fenske, Aminoff, & Bar, 2005). Among these previous studies, Zago et al. (2005) is unique in their examination of the "rise and fall" pattern in a fine timescale. They presented color photographs of familiar objects, and participants identified the objects as natural or manmade. The magnitude of priming increased with short presentation of primes (40–250 ms) but decreased with longer presentation (350–1900 ms). The researchers observed that the rise and fall pattern was present with the maximal magnitude of priming for 250 ms of previous stimulus exposure.

They explained this pattern by introducing a combined model of "sharpening" (Desimone, 1996) and "selection" (Wiggs & Martin, 1998). According to this model, the short presentation of a previous stimulus improves the coding of stimulus features and sharpens object representation. Longer presentation, however, elicits a selection process based on high-level information and semantic knowledge. Selection leads to the continued representation of the features essential for identifying the object and the discarding of non-essential features. Therefore, overlapping features between the representation of the previous stimulus and the target decrease, reducing the magnitude of priming.

Although the combined model of sharpening and selection explains the rise and fall pattern, it is only one possible explanation, and it requires validation as well as allows for other accounts. Sharpening is supported by physiological evidence, which indicates that neurons in the inferior temporal cortex of macaque monkeys represent only global properties of stimuli at ~130 ms, before becoming more stimulus-specific at ~240 ms (Tamura & Tanaka, 2001). It is, however, not as well supported that selection leads to the "fall" pattern of priming, because selection is considered to cause a faster and more efficient behavioral response (Wiggs & Martin, 1998). Considering that the task requirement in Zago et al. (2005) was to judge whether the objects were natural or manmade, selection of the essential features for identifying a certain object should have been highly beneficial, and we could argue that selection should have increased rather than decreased the magnitude of priming. Therefore, we need an alternative account for the fall of priming.

We must also note that perceptual priming and conceptual priming might have co-occurred in Zago et al. (2005), given the properties of their task and stimuli. Considering that perceptual and conceptual priming have different attributes and depend on distinct neural mechanisms

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(Voss, Schendan, & Paller, 2010), research must identify the factors involved in forming the rise and fall pattern.

To address the aforementioned issues, we examined the rise and fall pattern of priming under conditions in which conceptual processes (selection and conceptual priming) are not likely to arise. An effective method of excluding the influences of conceptual processes is to use stimuli without pre-existing memory (DeSchepper & Treisman, 1996; Musen & Treisman, 1990; Schacter, Cooper, & Delaney, 1990; Voss & Paller, 2010a). We used the meaningless kaleidoscope images introduced by Voss and colleagues (Voss, Baym, & Paller, 2008; Voss & Paller, 2010a) and employed a color-decision task similar to that in their studies. In the present study's Experiment 1, participants judged the number of colors in minimally meaningful and difficult-to-recognize kaleidoscope images. If the rise and fall pattern is replicated under the conditions of the present experiment, the fall cannot be explained by selection with higher-level semantic information.

1.2. Implicit memory processes in recognition memory tests

Another question is whether the rise and fall of performance is specific to priming or more generally observed for implicit memory. To investigate this question and elucidate the underlying mechanism, we compared the impact of stimulus duration on priming in Experiment 1 with that on the recently reported phenomenon of "implicit recognition" in Experiment 2.

One of the most fundamental topics in the study of memory is the dissociation between implicit and explicit memory (Graf & Schacter, 1985; Schacter & Tulving, 1994). Most studies have attempted to demonstrate one-to-one correspondence between performances of a certain task and a certain memory (Berry, Shanks, & Henson, 2008). In this view, the priming task is considered to be driven only by implicit memory and the recognition task only by explicit memory.

However, several studies suggest that recognition judgments might be affected by implicit memory (Jacoby & Whitehouse, 1989; Rajaram, 1993; Tunney & Fernie, 2007). In these studies, target stimuli primed by a masked preceding stimulus were likely to be recognized as old. Furthermore, recent studies have more clearly demonstrated the contribution of implicit memory to recognition memory performance (Vargas, Voss, & Paller, 2012; Voss & Paller, 2009; Voss & Paller, 2010b; Voss et al., 2008). In Voss and Paller (2009), participants studied kaleidoscope images in either a full- or divided-attention condition. In a forced-choice recognition test, participants selected the old image and reported their awareness of memory via a remember/know/guess procedure. Surprisingly, performance was better under the divided-attention condition than under the full-attention condition. Moreover, accurate recognition occurred without conscious awareness of memory; the accuracy of the "guess" response was very high and was even higher than that of the "know" response. This implicit recognition was associated with the N300 effect in the evoked potentials; it was similar to that associated with perceptual priming and was distinct from the positive brain potential associated with recollection and familiarity. These results supplement their argument that implicit recognition and priming depend on similar implicit memory mechanisms.

These findings indicate a crucial contribution of implicit memory processes to recognition performance. This implicit recognition, however, is highly elusive, difficult to replicate (Jeneson, Kirwan, & Squire, 2010), and demands many strict prerequisites (Voss & Paller, 2010b). Furthermore, there is little behavioral evidence indicating that implicit recognition relies on implicit memory processes; existing evidence merely suggests that lateralized visual fluency may be responsible for implicit recognition (Vargas et al., 2012).

In Experiment 2, to obtain insights into possible common mechanisms, we assessed whether implicit recognition exhibits dependence that is similar to that of priming on stimulus duration. As previously mentioned, the magnitude of priming rises and falls with stimulus duration. Therefore, if implicit recognition and priming are based on similar implicit memory processes, the performance of implicit recognition would vary following the same time course as that of the magnitude of priming. Using kaleidoscope images similar to those in Experiment 1, Experiment 2 investigated whether implicit recognition shows the fall pattern, because we consider this unique and counterintuitive fall pattern as the most characteristic feature of the temporal dynamics of priming.

2. Experiment 1

We investigated the time course of priming using meaningless kaleidoscope images. Because of the small number of available images, we assessed the "rise" and "fall" for different groups of participants (referred to as the "brief" and "long" conditions, respectively).

2.1. Materials and Methods

2.1.1. Participants

A total of 32 students from Kyoto University volunteered to participate in Experiment 1: 16 (11 men, 5 women; ages 18–24 years) participated in the brief condition and the remaining 16 (12 men, 4 women; ages 19–28 years) participated in the long condition. They were paid according to the Kyoto University standard. All participants had normal color vision.

2.1.2. Materials and procedure

Courtesy of Dr. Voss, we used 180 kaleidoscope images introduced in Voss et al. (2008) and Voss and Paller (2010a). Among these images, 90 contained three colors and the remaining contained four or five colors. Images were randomly assigned to experimental blocks for each participant and were displayed on a dark background on a computer monitor (23″ Apple Cinema Display) using the software Presentation (Neurobehavioral Systems).

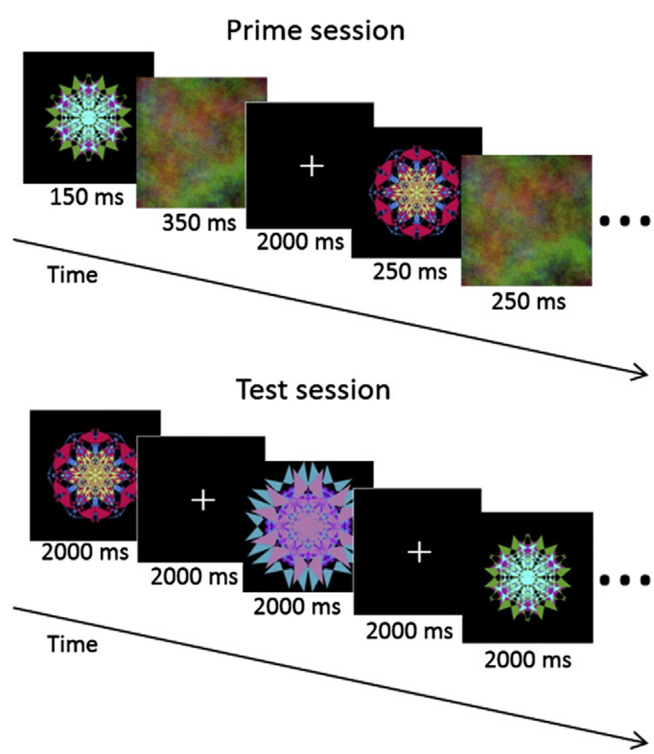

Fig. 1. Trial presentation sequence in the brief condition. In the prime sessions, kaleidoscope images were alternately presented for either 150 or 250 ms. In the test sessions images were presented for 2000 ms. Participants judged whether each image contained three colors.