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Encoding of episodic information through fast task-irrelevant perceptual learning

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ABSTRACT

The mechanisms guiding our learning and memory processes are of key interest to human cognition. While much research shows that attention and reinforcement processes help guide the encoding process, there is still much to know regarding how our brains choose what to remember. Recent research of task-irrelevant perceptual learning (TIPL) has found that information presented coincident with important events is better encoded even if participants are not aware of its presence (see Seitz & Watanabe, 2009). However a limitation of existing studies of TIPL is that they provide little information regarding the depth of encoding supported by pairing a stimulus with a behaviorally relevant event. The objective of this research was to understand the depth of encoding of information that is learned through TIPL. To do so, we adopted a variant of the "remember/know" paradigm, recently reported by Ingram, Mickes, and Wixted (2012), in which multiple confidence levels of both familiar (know) and remember reports are reported (Experiment 1), and in which episodic information is tested (Experiment 2). TIPL was found in both experiments, with higher recognition performance for target-paired than for distractor-paired images. Furthermore, TIPL benefitted both "familiar" and "remember" reports. The results of Experiment 2 indicate that the most confident "remember" response was associated with episodic information, where participants were able to access the location of image presentation for these items. Together, these results indicate that TIPL results in a deep enhancement in the encoding of target-paired information.

1. Introduction

Memory is a limited resource (Miller, 1956). We are unable to encode and store all the information present in the environment, and such exhaustive memorization would lead to difficulties in effectively utilizing stored information quickly and effectively to guide behavior. While people often want a memory system that follows their direction and stores information that they deem important, such as "my keys are on the dresser", it is well known that memory is not so obedient, "where are my keys and I can't get that Barney song out of my head". While much research shows that attention and reinforcement processes help guide the encoding process (Broadbent, 1958; Cowan, 1988; Craik et al., 1996; Seitz, Lefebvre, et al., 2005; Seitz & Watanabe, 2003, 2005), there is still much to know regarding how our brains choose what to remember.

Recent research has found that stimuli presented at temporally-coincident times with important events are better encoded even if participants are not aware of their presence (see Seitz & Watanabe, 2009). For example, stimuli presented with a task-target are better learned than those presented with task distractors (Dewald, Sinnett, & Doumas, 2011; Leclercq & Seitz, 2012a, 2012b, 2012c, 2012d; Lin et al., 2010; Swallow & Jiang, 2010, 2011). This effect was called the task irrelevant perceptual learning (TIPL). TIPL has been observed in different learning paradigms. It has been studied in detail in the case of low-level perceptual learning (Seitz & Watanabe, 2005; see also Seitz & Watanabe, 2009 for a review), and more recently for perceptual memories with the study of a fast form of TIPL (fast-TIPL) (Leclercq & Seitz, 2012a, 2012b, 2012c, 2012d). According to these studies, learning and memory is superior for stimuli that are correlated with important events whether or not these stimuli have been deemed "relevant" to the behavior.

However a limitation of existing studies of fast-TIPL is that they provide little information regarding the depth of encoding supported by pairing a stimulus with a behaviorally relevant event. For example, the superior memorization can be accounted for either because some features of the target-paired images are more salient (Perceptual Learning account), because the target-paired images are more familiar (Familiarity account), or because the target-paired images contained episodic information (Episodic account). In the Perceptual Learning account viewers may not remember the target-paired images, per se, however, they report images as being familiar when some features of the images seem

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more salient than some baseline. In the Familiarity account (Tulving, 1985), the target-paired images may be better encoded in a semantic memory, without any episodic information regarding the encoding experience (i.e. no memory of the screen-location of the image when encoded). Finally, in the Episodic account (Tulving, 1985), there may be some memory of the encoding episode (e.g. remembering screen-location of the image or where it was within the image stream). Tulving (1985) suggested that memory types could be dissociated through the questions used to probe the memory; such requiring the observer to report whether they are "familiar" with or "remember" an object. Such approaches are commonly used to dissociate between memory systems in the brain and have led to the dual-process theories of recognition memory (Atkinson & Juola, 1973, 1974; Hintzman & Curran, 1994; Jacoby, 1991; Jacoby & Dallas, 1981; Mandler, 1980; Wixted, 2007; Yonelinas, 1994). While the dual-process theories are controversial (Donaldson, 1996; Dunn, 2004, 2008) and conclusions based on dissociations of memory reports must be considered carefully, using multiple memory reports with confidence scales can provide a useful approach to understand the memory processes.

Accordingly, we chose to adopt a method from Ingram, Mickes, and Wixted (2012) as a useful framework to better understand the depth of memory that could be elicited through fast-TIPL (Leclercq & Seitz, 2012a). We first conducted Experiment 1 to understand the effect of the target-pairing on the memory and then replicated these results in Experiment 2 where we also tested for episodic information associated with remembered items. Both experiments showed that fast-TIPL boosted both remember and familiar judgments for target-paired items compared to distractor-paired items, and results of Experiment 2 indicated that fast-TIPL can facilitate encoding of episodic information associated with target-paired items.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Seventy-five participants took part to the first experiment, but only 63 participants (41 females, 22 males; ages 18–36) were included in the data analysis. Participants were excluded ($n = 12$) either because they failed to respond on the majority of trials in the Rapid Serial Visual Presentation (RSVP) task or because they had more false-positives than hits on the Image Recognition Task. Of note, when all participants are included in the analyses, none of the statistical effects change in significance. Participants gave written informed consent to participate in this experiment, which was approved by the Human Research Review Board of the University of California, Riverside. All participants reported normal or corrected-to-normal visual acuity and received course credit and financial compensation for the 40-min session.

2.1.2. Apparatus and stimuli

An Apple Power Mac G4 running Matlab (Mathworks, Natick, MA) and Psychtoolbox Version 3 (Brainard, 1997; Pelli, 1997) was used for stimulus generation and experiment control. Stimuli were presented on a 22″ CRT monitor with resolution of 1600×1200 and a refresh rate of 100 Hz. Participants sat with their eyes approximately 60 cm from the screen. The backgrounds of all displays were a mid-gray. Display items consisted of 700×700 pixel (18.3 degrees of visual angle) photographs depicting natural or urban scenes from eight distinct categories (i.e., mountains, cityscapes, etc.). Images were obtained from the LabelMe Natural and Urban Scenes database (Oliva & Torralba, 2001) at 250×250 pixels of resolution, then up-sampled to 700×700 pixels of resolution.

2.1.3. Procedure

During this experiment, the participants were required to perform successively a letter detection task and then an image detection task.

2.1.3.1. Letter detection task. In each trial, a stream of 10 images was successively presented in the middle of the screen. Each image was presented 133 ms, followed by a blank ISI of 367 ms for a SOA of 500 ms (Fig. 1). A gray aperture (1 degree of visual angle and luminance of 92 cd/m^2) was presented in the center of each image, thus centered in the middle of the screen. Each image was presented with a letter (0.75 degree of visual angle, Font Courier, Size 32) in the middle of the gray aperture. This letter could be a distractor (black letter; luminance of 0.25 cd/m^2) or a target (white letter; luminance of 250 cd/m^2). Each letter had the same onset and offset times as the image with which it was paired. In each trial, 1 image out of the 10 presented was paired with a white target letter; the others 9 images were paired with black distractor letters. The white target letter could appear in position 3 to 8. The type of stimulus that an image coincided with (e.g. a target or a distractor) was held constant across the experiment. For one set of 120 images, 20 images were paired with the white letters (targets) and the remaining 100 images were paired with black letters (distractors), also presented from position 3 to 8 (to control for primacy and recency effects). Image assignment to target and distractor was random for each participant. A set of 80 filler images, for which no target was presented, was used with letters presented in positions 1, 2, 9 and 10. These fillers images were not tested in the image recognition test. Each image was presented 10 times during the entire experiment. Participants were asked to memorize the identity of the white letter and the images. At the end of each trial, participants pressed the key corresponding to the white letter. Participants performed a practice block of 12 trials. Each participant was then tested for a total of 200 trials, in 10 blocks of 20 trials. Breaks were given between blocks and subjects had to press the space bar on the keyboard to start the next one.

2.1.3.2. Image recognition task. At the end of the experiment, participants performed an image recognition task. Eighty images were presented to the participants: the 20 images paired with the target, 20 images paired with the distractors (randomly assigned for each participant) and 40 new images never presented in the experiment. One image was presented at a time until participants made their response. For each image, participants were asked to make an old/new decision about this image. To do so we used a rating scale with six levels (Ingram, Mickes, & Wixted, 2012; Experiment 2) illustrated in Fig. 2. A response of 1–3 was used to indicate their confidence that the image was new, while a response of 4–6 was used to indicate their confidence that the image was old. In other words, 1 indicated the highest confidence that the image was new, and 6 indicated the highest confidence the image was old. Old ratings of 4–6 were further parsed by familiarity and remember options (4F, 5F, and 6F; 4R, 5R, and 6R) where F means familiar and R means remember. Responses were recorded on the number pad and stickers were placed over the numbers 4–9 with 4–6 used for the R-scale and 7–9 for the F-scale. This scale provided a visual indication for the participants that remember judgments can also be made without the highest confidence. Participants made old–new decisions by clicking on a digit corresponding to their response. For the R or F responses, participants were told that they have to respond R if they can remember some qualitative information about the item (such as recollecting what you thought about