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Research report

The role of multisensory memories in unisensory object discrimination

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Abstract

Past multisensory experiences can influence current unisensory processing and memory performance. Repeated images are better discriminated if initially presented as auditory–visual pairs, rather than only visually. An experience's context thus plays a role in how well repetitions of certain aspects are later recognized. Here, we investigated factors during the initial multisensory experience that are essential for generating improved memory performance. Subjects discriminated repeated versus initial image presentations intermixed within a continuous recognition task. Half of initial presentations were multisensory, and all repetitions were only visual. Experiment 1 examined whether purely episodic multisensory information suffices for enhancing later discrimination performance by pairing visual objects with either tones or vibrations. We could therefore also assess whether effects can be elicited with different sensory pairings. Experiment 2 examined semantic context by manipulating the congruence between auditory and visual object stimuli within blocks of trials. Relative to images only encountered visually, accuracy in discriminating image repetitions was significantly impaired by auditory–visual, yet unaffected by somatosensory–visual multisensory memory traces. By contrast, this accuracy was selectively enhanced for visual stimuli with semantically congruent multisensory pasts and unchanged for those with semantically incongruent multisensory pasts. The collective results reveal opposing effects of purely episodic versus semantic information from auditory–visual multisensory events. Nonetheless, both types of multisensory memory traces are accessible for processing incoming stimuli and indeed result in distinct visual object processing, leading to either impaired or enhanced performance relative to unisensory memory traces. We discuss these results as supporting a model of object-based multisensory interactions.

Theme: Sensory systems
Topic: Visual psychophysics and behavior

Keywords: Multisensory; Auditory; Visual; Somatosensory; Memory; Object recognition; Discrimination

1. Introduction

Investigations of memories' or past experiences' influence(s) on the treatment of incoming stimuli have predominantly focused on unisensory memories (e.g., Ref. [27]). However, multisensory experiences are believed to enrich our memories and influence ongoing sensory processes. Recent studies using hemodynamic measures (fMRI and PET) have examined how experiences in one or multiple senses alter later processing of stimuli in another sensory modality, providing evidence that brain regions involved in the encoding of an experience are also involved during its subsequent retrieval [19,33]. Intracranial microelectrode recordings in monkeys provide similar evidence by demonstrating that neuronal responses in visual object recognition areas are selective for multisensory-learned associations [10].

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These collective data show that neurophysiological responses, both within an area as well as across a brain network, to an incoming unisensory stimulus can vary according to whether it is part of a multisensory or unisensory memory.

Our recent behavioral and electrical neuroimaging study investigated the discrimination between unisensory (visual) and multisensory (auditory–visual) memories, providing data on when and where these effects first take place. While performing a continuous recognition task that required the differentiation of newly and already viewed images, subjects incidentally discriminated the repeated presentations of images according to their prior presentation as either a visual stimulus or auditory–visual (AV) pair. Stimuli with multisensory pasts were more accurately discriminated as having already been seen. This effect was observed in the absence of explicit studying of the auditory–visual pairs. Moreover, this discrimination was present electrophysiologically at just 60 ms and manifested as a change in the active areas of the brain within the lateral–occipital complex [17]. This was taken as evidence of the distinct representation of unisensory and multisensory events. As such, this study demonstrated that the functional consequences of the variations in cerebral activity following multisensory memory representations can be observed both electrophysiologically and, critically for the present study, behaviorally. Unresolved, however, are the kinds of memory traces that support this later discrimination, as well as whether all combinations of multisensory stimuli would suffice.

The aim of the present investigation was to determine what kinds of multisensory experiences are required to produce distinct perceptual/memory traces that can later be differentially retrieved upon repetition of the visual component. The use of meaningful auditory–visual stimulus pairs that always corresponded semantically across sensory modalities obfuscated our ability to address the requisites for establishing distinct perceptual/memory representations. One possibility is that the mere simultaneous presentation (i.e., a purely episodic context) of any auditory stimulus with visual objects would suffice. In which case, one would anticipate similar performance benefits irrespective of the nature of the multisensory experience. A parallel issue concerns whether or not equally effective, distinct perceptual/memory representations result from somatosensory–visual events. Both of these examples address the more general question of whether episodic multisensory experiences, which are orthogonal to the required task, cannot only result in perceptual/memory traces distinct from those for unisensory experiences, but also be later accessible upon presentation of just the visual component. Experiment 1 therefore examined the efficacy of episodic memory traces and whether different sensory combinations are equally effective by pairing visual object stimuli with either pure tones or somatosensory vibrations on distinct blocks of trials. A second (non-exclusive) possibility is that distinct perceptual/memory traces are established only after extensive semantic processing. In this case, performance would only be improved if stimuli presented to the different senses imparted information about the same object. That is, the above-mentioned distinct perceptual/memory traces would be for specific objects, rather than general visual experiences. Experiment 2 tested this by manipulating the congruence between auditory and visual object stimuli within blocks of trials.

2. Materials and methods

2.1. Participants

Experiment 1 included 16 (9 female) volunteers aged 21–31 years (mean ± SD = 26.7 ± 0.8). A different cohort of 11 subjects (8 female), aged 23–32 years (mean ± SD = 25.6 ± 0.9) participated in Experiment 2. All subjects provided written, informed consent to participate in the study, the procedures of which were approved by the Ethical Committee of the University of Lausanne. Of the 27 subjects, 24 were right-handed [20]. No subject had a history of or current neurological or psychiatric illnesses, and all reported normal or corrected-to-normal vision as well as normal hearing and touch.

2.2. Procedures

Both experiments had subjects perform a continuous recognition task comprised of equal numbers of initial and repeated presentations of line drawings that were pseudo-randomized with a block of trials (see also Ref. [17]). The line drawings were of common objects selected from either a standardized set [28] or obtained from an online library (dgl.microsoft.com) and modified to stylistically resemble those from the standardized set. The selected images contained an equivalent number of objects from different semantic categories (e.g., animals, tools, musical instruments, vehicles, miscellaneous household items, etc.) that were equally subdivided across experimental conditions. Images appeared black on a white background and were positioned centrally on a computer monitor (Philips Brilliance 202P4) located 114 cm from the subject. Images subtended an average of ~4.5° (±1.2°) in both the vertical and horizontal planes. On initial presentations, visual stimuli could either be presented with or without a sound or somatosensory vibration (the details of which are provided below).

The image set was equally divided into two groups: those that upon initial presentation appeared only visually and those that appeared as a simultaneous multisensory pair. On repeated presentations, only the visual stimuli from the initial presentations were displayed. Subjects' task was to indicate as quickly and as accurately as possible whether the image was being presented for the initial or repeated time. Thus, there were two classes of repeated presentations: (1)