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Visual motion disambiguation by a subliminal sound

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Abstract

There is growing interest in the effect of sound on visual motion perception. One model involves the illusion created when two identical objects moving towards each other on a two-dimensional visual display can be seen to either bounce off or stream through each other. Previous studies show that the large bias normally seen toward the streaming percept can be modulated by the presentation of an auditory event at the moment of coincidence. However, no reports to date provide sufficient evidence to indicate whether the sound bounce-inducing effect is due to a perceptual binding process or merely to an explicit inference resulting from the transient auditory stimulus resembling a physical collision of two objects. In the present study, we used a novel experimental design in which a subliminal sound was presented either 150 ms before, at, or 150 ms after the moment of coincidence of two disks moving towards each other. The results showed that there was an increased perception of bouncing (rather than streaming) when the subliminal sound was presented at or 150 ms after the moment of coincidence compared to when no sound was presented. These findings provide the first empirical demonstration that activation of the human auditory system without reaching consciousness affects the perception of an ambiguous visual motion display.

Keywords: Subliminal sound; Visual motion; Cross-modal; Audiovisual integration

1. Introduction

The ability to respond to external stimuli is enhanced by binding signals from multiple sensory modalities. Studies of perceptual illusions such as the ventriloquist and the McGurk effect in which conflicting multisensory information is erroneously perceived to be bound together suggest that cross-modal binding is a fast and pre-attentive process (Driver, 1996; McGurk & MacDonald, 1976; Sekuler, Sekuler, & Lau, 1997). However, there has recently been much debate regarding cross-modal illusion perception, and the confounding influence of response bias and other decision factors (Bertelson & de Gelder, 2004).

The "bouncing–streaming" illusion involves two objects moving towards one another, reaching the same position, and then moving apart. This motion can be perceived as the objects moving in either a constant tra-

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jectory (i.e., streaming through one another) or a reverse trajectory (i.e., bouncing off one another as if following a collision). The possible subjective and interpretative effects of the sound influence in the bouncing–streaming visual illusion (Sekuler et al., 1997) have recently been addressed (Sanabria, Correa, Lupianez, & Spence, 2004). It has been shown (Sekuler et al., 1997) that the perception of bouncing can be increased by a sound at the moment of contact, suggesting that the sensory information perceived in one modality (audition) can modulate the perception of events occurring in another modality (i.e., ambiguous visual motion perception). However, this cross-modal effect may simply reflect a cognitive bias whereby the sound resembles the transient auditory stimulus produced by a physical collision of two objects, causing subjects to infer the reversal of motion direction from the presence of this factor generally associated with bouncing in the physical world.

Cognitive biases linked to subjective reports in the sound bounce-inducing effect have recently been ruled out by an elegant paradigm (Sanabria et al., 2004) in which the point of coincidence of two moving disks was hidden behind an occluder. When emerging from behind the occluder, the disks (one red, the other blue) could either follow the same trajectory (streaming) or else move in the opposite direction (bouncing). Participants made speeded discrimination responses regarding the side from which one of the disks emerged from behind the occluder. Participants responded more rapidly on streaming trials when no sound was presented compared to 'streaming with sound' trials, and also responded more rapidly on bouncing trials when sound was presented at the moment of coincidence compared to 'bouncing without sound' trials. Although this paradigm provides an implicit/objective behavioral measure of the sound bounce-inducing effect, it does not rule out interpretative response biases whereby subjects explicitly infer the reversal of motion direction from the presence of the sound even when the collision is not visible.

The present study used a novel method to overcome the issue of interpretative bias in the sound bounce-induced effect. The approach involved stimulating the auditory system without the subject being conscious of the stimulation. This was achieved by presenting a subliminal sound either 150 ms before, at, or 150 ms after the moment of coincidence of two disks. An increase in the proportion of "bounce" responses in the presence of a subliminal sound would be inconsistent with a cognitive bias regarding the bounce-inducing effect.

2. Experiment 1

2.1. Methods

2.1.1. Subjects

The study involved 12 subjects (6 females and 6 males) who were paid volunteers and were unaware of the purpose of the experiment. Importantly, the subjects were not aware of the presence of a subliminal sound during the visual motion experiment. The experiment took approximately 20 min to complete and was performed in accordance with the ethical standards stated in the 1964 Declaration of Helsinki. Informed consent was obtained after the nature and possible consequences of the studies were explained. Audiograms (1702 Audiometer Grason-Stadler®) in the 250–8000 Hz range were performed, and all subjects exhibited normal hearing.

2.1.2. Materials

Visual stimuli were presented on a 15-in. VGA computer monitor in a dimly illuminated room. Sounds were presented through head phones. The synchrony between the auditory and visual stimuli was physically verified by measuring the output signal of the computer soundboard and the photometer signal at the point of coincidence of the two disks. Inter-stimuli time intervals were then adjusted with respect to the soundboard and computer screen asynchrony.

2.1.3. Procedure

2.1.3.1. Auditory threshold. Prior to the "visual motion" experiment, an auditory detection threshold for a brief sound was assessed for each subject. Through head phones, the subjects heard a white noise (20–20,000 Hz) of 2 s in duration and 65 dB SPL. A pure tone (500 Hz) of 10 ms in duration was presented 400, 800 or 1200 ms after the beginning of the white noise. Subjects performed a forced-choice detection task: