Auditory Motion in Depth is Preferentially ‘Captured’ by Visual Looming Signals *

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Abstract
The phenomenon of crossmodal dynamic visual capture occurs when the direction of motion of a visual cue causes a weakening or reversal of the perceived direction of motion of a concurrently presented auditory stimulus. It is known that there is a perceptual bias towards looming compared to receding stimuli, and faster bimodal reaction times have recently been observed for looming cues compared to receding cues (Cappe et al., 2009). The current studies aimed to test whether visual looming cues are associated with greater dynamic capture of auditory motion in depth compared to receding signals. Participants judged the direction of an auditory motion cue presented with a visual looming cue (expanding disk), a visual receding cue (contracting disk), or visual stationary cue (static disk). Visual cues were presented either simultaneously with the auditory cue, or after 500 ms. We found increased levels of interference with looming visual cues compared to receding visual cues, compared to asynchronous presentation or stationary visual cues. The results could not be explained by the weaker subjective strength of the receding auditory stimulus, as in Experiment 2 the looming and receding auditory cues were matched for perceived strength. These results show that dynamic visual capture of auditory motion in the depth plane is modulated by an adaptive bias for looming compared to receding visual cues.

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Keywords
Multisensory, motion, depth, dynamic capture, looming, receding

1. Introduction

Objects and events in the environment often provide information to both the visual and auditory systems, and the combination of information from the different sensory modalities is a fundamental task of the perceptual system (Stein and Meredith, 1993). While much research into multisensory processing has focussed on station-
ary cues, a growing body of research has begun to investigate the integration of moving signals, in recognition that many important features of the external world are dynamic (for review, see Soto-Faraco et al., 2003). Crucial for appropriate behavioural responses, and often critical for survival, is the rapid detection of looming motion in the depth plane which can signal the approach of a potentially threatening object. The accurate detection of receding motion is also important, as this may indicate that a dangerous object is retreating. Both the visual and auditory modalities can provide reliable information about looming and receding motion.

Several lines of evidence have provided insight into the interactions between visual and auditory motion cues in the depth plane. Motion adaptation after-effects have been found which show that adaptation to motion in one modality can influence the perceived direction of a motion stimulus in a second modality (Jain et al., 2008; Kitagawa and Ichihara, 2002), and directional congruence between visual and auditory signals in the depth plane has been shown to influence discrimination thresholds (Röhrbein and Zetzsche, 2000). Furthermore, a stationary auditory stimulus can be perceived as moving when presented simultaneously with a moving visual stimulus; this effect is known as ‘dynamic capture’ (Mateeff et al., 1985). Dynamic capture has additionally been shown to lead to the illusory perception of motion in the direction of a simultaneously-presented visual stimulus, when the auditory stimulus is physically moving in the opposite direction, both for horizontally moving cues (Jain et al., 2008; Soto-Faraco et al., 2002, 2004, 2005), for vertically moving signals (Jain et al., 2008) and for motion in the depth plane (Jain et al., 2008; Kitajima and Yamashita, 1999).

Kitajima and Yamashita’s (1999) demonstration of dynamic capture of motion in depth used a binocularly fused square that appeared to approach or recede from the participant together with an auditory motion stimulus that moved physically in space, while Jain et al. (2008) employed as a visual stimulus a concentric grating stimulus that moved radially outward or inward. Despite these differences in the stimuli, both experiments found that a visual motion cue could influence the perceived direction of an auditory stimulus moving in the depth plane. Importantly however, neither of the above studies performed a formal investigation to test for differences in the degree of dynamic capture induced by looming and receding stimuli. That such a difference may exist is based on research indicating a perceptual bias for looming visual (Ball and Tronick, 1971; Schiff et al., 1962) and auditory signals (Neuhoff, 1998), compared to receding cues, which is thought to reflect the behavioural salience of objects that are approaching rather than receding. Indeed recent work has revealed increased speeding of reaction times for multisensory looming signals compared to multisensory receding signals (Cappe et al., 2009), and a bias towards auditory-visual looming compared to receding cues in monkeys (Maier et al., 2004). These two studies of crossmodal processing of looming and receding signals have examined situations where the visual and auditory cues provide consistent information about direction of motion. It is not yet clear whether visual looming cues would show a greater degree of dominance (i.e., capture) over audi-