Behavioral/Cognitive

Action and Perception Are Temporally Coupled by a Common Mechanism That Leads to a Timing Misperception

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We move our eyes to explore the world, but visual areas determining where to look next (action) are different from those determining what we are seeing (perception). Whether, or how, action and perception are temporally coordinated is not known. The preparation time course of an action (e.g., a saccade) has been widely studied with the gap/overlap paradigm with temporal asynchronies (TA) between peripheral target onset and fixation point offset (gap, synchronous, or overlap). However, whether the subjects perceive the gap or overlap, and when they perceive it, has not been studied. We adapted the gap/overlap paradigm to study the temporal coupling of action and perception. Human subjects made saccades to targets with different TAs with respect to fixation point offset and reported whether they perceived the stimuli as separated by a gap or overlapped in time. Both saccadic and perceptual report reaction times changed in the same way as a function of TA. The TA dependencies of the time change for action and perception were very similar, suggesting a common neural substrate. Unexpectedly, in the perceptual task, subjects misperceived lights overlapping by less than ~100 ms as separated in time (overlap seen as gap). We present an attention-perception model with a map of prominence in the superior colliculus that modulates the stimulus signal's effectiveness in the action and perception pathways. This common source of modulation determines how competition between stimuli is resolved, causes the TA dependence of action and perception to be the same, and causes the misperception.

Key words: **attention; gap effect; model; saccades; superior colliculus**

Introduction

Visual stimuli compete to be the target for an eye movement, but they also compete to be the object for perception. Action and perception should solve these competitions in a temporally coordinated fashion. Otherwise, we might make a movement away from an object before it can be perceived, or we might delay making a movement toward an object we need to see (Gibson, 1979). However, visual information for action and perception is processed in different areas (Ungerleider, 1982; Milner and Goodale, 2008). These areas are thought to interact (Schenk and McIntosh, 2010; Cloutman, 2013), e.g., motor processing is known to influence attention and thus perception (Kowler, 2011), but it is not known whether this interaction implies a temporal coupling between action and perception (Gibson, 1979; Warren Jr, 1990; Prinz, 1997; Goodale, 2001). Thus, whether how and where action and perception are temporally coupled remains to be elucidated. To address these questions, we studied temporal coupling between action and perception in the classic gap/overlap paradigm.

The time course of motor preparation has been extensively studied by measuring the saccadic reaction time (SRT) in a task with variable temporal asynchrony (TA) between the time of fixation point offset and the time of target onset. Saslow (1967) first described the gap effect, the dependence of SRT upon TA: compared with the synchronous condition, SRT is reduced when the fixation point turns off before the target turns on (gap condition), and is increased when the fixation point turns off after the target turns on (overlap condition).

The subject's perception in Saslow's task has not been reported in the literature. Although a motor dependence upon temporal asynchrony does not imply a perceptual dependence, the time and content of perception might also depend upon the temporal asynchrony. In that case, the temporal asynchrony dependencies of action and perception might be either loosely or tightly coupled. A tight coupling would suggest that temporal coordination occurs through a common neural mechanism.

We looked for temporal coupling in a gap/overlap dual-task in which subjects made saccades to targets appearing with variable temporal asynchrony, and also reported (by a button press) whether they perceived a gap or an overlap between the stimuli. Saccadic reaction time, perception report reaction time (PRT), and perception were analyzed as functions of temporal asyn-

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