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# Goal-directed action is automatically biased towards looming motion

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ABSTRACT

It is known that looming motion can capture attention regardless of an observer's intentions. Real-world behavior, however, frequently involves not just attentional selection, but selection for action. Thus, it is important to understand the impact of looming motion on goal-directed action to gain a broader perspective on how stimulus properties bias human behavior. We presented participants with a visually-guided reaching task in which they pointed to a target letter presented among non-target distractors. On some trials, one of the pre-masks at the location of the upcoming search objects grew rapidly in size, creating the appearance of a "looming" target or distractor. Even though looming motion did not predict the target location, the time required to reach to the target was shorter when the target loomed compared to when a distractor loomed. Furthermore, reach movement trajectories were pulled towards the location of a looming distractor when one was present, a pull that was greater still when the looming motion was on a collision path with the participant. We also contrast reaching data with data from a similarly designed visual search task requiring keypress responses. This comparison underscores the sensitivity of visually-guided reaching data, as some experimental manipulations, such as looming motion path, affected reach trajectories but not keypress measures. Together, the results demonstrate that looming motion biases visually-guided action regardless of an observer's current behavioral goals, affecting not only the time required to reach to targets but also the path of the observer's hand movement itself.

## 1. Introduction

Everyday behaviors often require reaching towards objects in order to manipulate them in a goal-directed fashion. For example, cooking dinner might involve turning down the stove, grabbing a spice jar, and then reaching to a spatula. These actions are often executed in the context of a cluttered environment, such as a messy kitchen, where multiple objects compete for attention and action.

In such an environment, selection of a single object for more detailed processing is typically required for a guided action response (e.g., Song & Nakayama, 2006). In many cases attentional selection can be guided towards task-relevant properties in a top-down fashion based on current behavioral goals (e.g., Egeth, Virzi, & Garbart, 1984; Gottlieb, 2007; Green & Anderson, 1956; Posner, 1980). However, sometimes the physical properties of an object can also automatically bias attentional selection regardless of an observer's intentions (e.g., Theeuwes, 1992; Yantis & Jonides, 1984). Guidance of selection for action can be broken down along similar lines; for example, objects matching task-relevant properties tend to compete more strongly for action (e.g., Castiello, 1999). However, action can also be automatically directed towards a perceptually salient object, such as a color singleton, even when that object is not task-relevant (e.g., Kerzel & Schönhammer, 2013; Wood et al., 2011).

One object property that is known to be behaviorally relevant, but whose impact on goal-directed action remains poorly understood, is looming motion. Looming motion, or a sudden increase in the perceived size of an object, is consistent with a rapidly approaching object and thus likely to signal threat to an observer. For example, looming motion would be perceived when a predator attacks, or when a ball is thrown in an observer's direction.

Previous studies have shown that when an attended object appears to loom, that object triggers an automatic behavioral response in infants and monkeys (e.g., Schiff, Caviness, & Gibson, 1962; Schmuckler, Collimore, & Dannemiller, 2007). Franconeri and Simons (2003) further showed that attention is automatically directed towards objects exhibiting looming motion even when attention is initially directed elsewhere. They proposed a *behavioral urgency hypothesis*, whereby stimuli that typically signal the need for an urgent behavioral response, such as looming objects,

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capture attention automatically (see also, e.g., von Mühlenen & Lleras, 2007). Lin, Franconeri, and Enns (2008) further showed that looming stimuli produce stronger attentional capture when they loom from the periphery and when they appear to be on a collision path with the observer.

These studies have focused on attentional selection. Attention and action are closely linked (e.g., Cisek, 2012; Song & Nakayama, 2009; Spivey & Dale, 2006), and a reach to a target among distractors requires a shift of focal attention (e.g., Song & Nakayama, 2006). Therefore, attentional selection provides a key roadmap for understanding selection for action. Indeed, a number of studies have shown that selection for action is guided in much the same way as attentional selection (e.g., Moher & Song, 2014; Song & Nakayama, 2006). However, action is not merely a readout of concluded higher-level cognitive processes like attention; instead, action plans may be initiated before the selection process is finalized (e.g., Song & Nakayama, 2008; Spivey, Grosjean, & Knoblich, 2005). Thus, the factors that guide attentional selection do not necessarily coincide with the factors that guide selection for action. In a recent study, Buetti and Kerzel (2009) examined the Simon Effect (e.g., Simon & Rudell, 1967) in both a keypress task and a reaching task. They found differences between the two measures; for example, the magnitude of the Simon Effect on response times was greater for a keypress response than a reaching response. Therefore, it is important to study guidance of selection for action separately from attentional selection, because in some cases these two processes may involve non-overlapping mechanisms (see also, e.g., Adam & Pratt, 2004).

In the present study, we examine whether looming motion automatically biases selection for action. One possible outcome is that goal-directed action is automatically biased towards looming objects, such that looming motion speeds responses when the looming object is a target, but looming motion disrupts performance when the looming object is a distractor. Another possibility is that selection of a looming object for action is more difficult than selection of a non-looming object because observers seek to avoid possible collisions (see e.g., Merchant et al., 2009; for a review of interception and collision avoidance). A third possibility is that looming has no effect on goal-directed action.

In Experiment 1, participants searched for and subsequently reached to a letter target in a three-object display. Prior to display onset, pre-masks appeared at the locations of the objects. On some trials, one of the pre-masks was initially small but grew in size over a brief period, and thus appeared to be "looming" in the direction of the participant from behind the display. We examine whether goal-directed action is biased towards looming objects by examining the temporal and spatial aspects of reach movements towards looming targets as well as non-looming targets in the presence of looming distractors. In Experiment 2, we vary the path of looming motion to explore whether objects on a collision path with the participant have more or less impact on goal-directed action. For both reaching experiments, we also present data from a similarly designed keypress version of the task to highlight the similarities and differences between traditional psychophysical approaches and visually-guided reaching studies in exploring the guidance of selection.

## 2. Experiment 1A: looming motion and goal-directed action

### 2.1. Materials and methods

Methods were largely adapted from Moher and Song (2013).

#### 2.1.1. Participants

Twelve Brown University undergraduates participated in the study in exchange for class credit (3 male, mean age: 20.2 years). All participants for all experiments reported here were right-handed with normal or corrected-to-normal vision and normal color vision. The protocol was approved by the Brown University Institutional Review Board in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. One participant was removed from analysis due to technical problems during the experiment.

#### 2.1.2. Apparatus

Stimuli were presented on an upright Plexiglas display facing the seated participant at a distance of approximately 48 cm. A projector behind the display projected the images onto the Plexiglas. An electromagnetic position and orientation recording system (Liberty, Polhemus) was used to record the three-dimensional hand position at a rate of approximately 160 Hz with a measuring error of .03 cm root mean square. A motion-tracking marker was fastened to the tip of each participant's right index finger using a Velcro strap. A Styrofoam block was placed 27 cm in front of the participant, between him or her and the display. This was the starting block on which participants rested their index finger at the beginning of each trial. Stimulus presentation was conducted using custom software designed with MATLAB (Mathworks) and Psychtoolbox (Brainard, 1997).

#### 2.1.3. Stimuli

All stimuli were presented on a black background. A fixation cross measuring 0.5 cm × 0.5 cm (0.6° of visual angle) appeared at the center of the screen before each trial. Three letters measuring 1.6 cm wide (1.9° of visual angle) and 2.7 cm tall (3.2° of visual angle) appeared on the screen during each trial. They were equally spaced and placed at 4, 8, and 12 o'clock positions on an imaginary circle surrounding fixation at a distance of 10 cm (11.9° of visual angle) from fixation. The letters closely resemble the block letters used in digital clocks so that any letter could be obtained from subtracting any of the seven line segments from a block 8. The letters used include: U, H, F, E, P, C, L, and S. Each display contained one target letter: either a U or an H, randomly selected for each trial. Participants were instructed to reach out and touch the target letter. On each trial, three "8"s appeared prior to the appearance of the stimuli. These figure 8s served as placeholder masks in order to prevent participants from beginning their search until the targets appeared. On looming trials, which consisted of half of all trials, one of the three "8"s initially appeared as 0.5 cm wide (0.6° of visual angle) and 0.9 cm tall (1.1° of visual angle) before rapidly expanding to its full size (300% increase in horizontal and vertical size at a linear growth rate) during the brief (150 ms) looming period (Fig. 1).

#### 2.1.4. Procedure

Nine-point hand calibration was conducted at the beginning of the experiment. Each trial began with a fixation cross at the center of the display. Participants were instructed to keep their finger in the starting position until the letter stimuli appeared. The trial would not proceed if the participant prematurely moved their finger off of the starting position. One second after the fixation cross appeared, three figure 8s appeared as placeholder pre-masks. In the looming condition, one randomly chosen placeholder mask appeared initially smaller than the others. After 1 s, the smaller mask grew to the same size as the other letters in the display over the course of 150 ms, resulting in the appearance of looming motion. The masks were then removed to reveal the letters immediately following the end of the looming animation. After every trial, an auditory feedback tone was played to indicate whether the participant's response was accurate (high-pitch beep) or inaccurate (low-pitch beep). If the participant did not touch one of the three letters within 1500 ms, the trial was marked as incorrect