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Can I reach that? Blind reaching as an accurate measure of estimated reachable distance

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ABSTRACT

Judgments of one's reach extent have been repeatedly found to be overestimated by about 10%. In 3 studies, a new dependent measure was employed in which participants viewed targets, closed their eyes, and then touched the location of the remembered target or pointed to its location if out of reach. This experimental paradigm yielded a much smaller but still present bias to over-estimate by about 2%. In addition, participants often reached for and touched target locations that were actually out of reach in a manner indicative of the typical 10% over-estimation bias. Surprisingly, participant response accuracy improved significantly and consistently across experimental trials even without visual or tactile feedback. This suggests that the proprioceptive information about the arm in space coupled with the remembered visual information about target location were sufficient to facilitate learning.

1. Introduction

Bruce Bridgeman had an abiding interest in the relationship between perception and action. Common sense suggests that perception precedes action. "See the ball. Hit the Ball." In the 1960s, evidence began to accumulate supporting the notion that perception and action were instead informed by parallel streams of visual processing (Held, 1970; Schneider, 1969; Trevarthen, 1968). Bridgeman (1991) was deeply interested in whether perception and action were informed by truly dissociable processes. In collaboration with Robert Post and Robert Welch, the following 2 criteria were set forth for valid comparisons between visual perception and visually guided action (Post, Welch, & Bridgeman, 2003):

- "The motor response is visually open-loop (i.e., no error-corrective visual feedback is provided).
- The perceptual-cognitive and motor responses refer to the same physical parameter of the environment (e.g., egocentric location or perceived direction, linear extent, motion)" (p. 146).

The current studies adhere to these criteria in investigating the relationship between perceptually based judgments of reachability and visually open-loop reaching responses.

Successfully interacting with the world depends upon knowing the boundaries of one's ability to act. Moving around in space, picking up objects, opening doors, and avoiding obstacles are among tasks that people consistently perform with success and without much effort or awareness. Deciding whether an action is possible requires a sensitivity to one's *action boundaries*, which are the extents over which actions can be performed (Fajen, 2005). For example, suppose that one sees a beer and decides to acquire it. If it is within arms' reach, then reaching is the behavior of choice, whereas if it is not, then walking to the beer may be required. Being

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aware of the extent of one's reach seems an important thing to know in making this decision, and thus, one would expect that judging the extent of one's reach would be accessible, reportable, and accurate. The literature, however, shows that, for perceived reachability, this is not the case.

The research literature finds consistent and reliable errors in individuals' estimations of how far they can reach. When shown a target and asked to make a binary yes/no judgment of its reachability, participants consistently over-estimated their reach (responded that they could reach targets that were too far away) when given unlimited time to report their judgment (Heft, 1993). Carello, Grosofsky, Reichel, Solomon, and Turvey (1989) observed participants over-estimate their arm's reach when targets were shown on a table that was both low (below waist height for standing participants) and at a normal height. Bootsma, Bakker, van Snippenberg, and Tdlohreg (1992) found that participants consistently over-estimated their ability to reach targets as they moved quickly in front of them. Reachability estimates were also inflated when participants were presented with overhead targets while standing upright, and while shown targets in front of and to the side of themselves when standing on both one and two feet (Fischer, 2000). Finally, Graydon, Linkenauger, Teachman, and Proffitt (2012) found that participants over-estimated their arm's reach when targets were presented at the midline or at varying angles on the side of a table contra-lateral to the to-be-reached with arm, regardless of anxiety levels (although anxiety did reduce the over-estimation bias). These studies all require that participants verbally report reachability estimates, and they display a consistent over-estimation bias of around 10% (Carello et al., 1989; Fischer, 2000; Gabbard, Cordova & Lee, 2007; Graydon et al., 2012; Heft, 1993; Linkenauger, Witt, Stefanucci, Bakdash, & Proffitt, 2009; Rochat & Wraga 1997; Robinovitch, 1998). This consistent over-estimation seems at odds with our ability to behave adroitly, and this inconsistency begs for an explanation.

Researchers studying the perception of walkable distances grappled with a similar conundrum in which verbally reported distance estimates were consistently underestimated. In response to this odd finding, an action-based measure was developed that typically evoked much higher accuracy. *Blind walking* is a measure of estimated walkable distance in which observers view a distance, closes their eyes, and then walk in a different direction until they believe they have covered the same distance as the viewed extent (Thomson, 1983). By replacing verbal judgments with an action measure, they eliminated the previously-observed compression bias – participants shown a 10 m distance, for example, might report that it was about 8 m long, but would walk the full 10 m when blind walking.

Reaching actions could show a similar resilience to the distortion endemic to verbal reports. Quite a bit of research has examined the accuracy of closed-loop actions, which are actions completed with continuous visual feedback, but the current study will be, to our knowledge, the first to examine the accuracy of open-loop reaching actions which, like blind walking, are executed without visual feedback.

In three studies, the present work explored the relationship between actions and judgments within the context of reaching. In all three studies, participants were seated at a table and shown a target at a series of distances on the tabletop in front of them. Their task was to look at the target, close their eyes, and respond in one of two ways. First, if the target appeared to be reachable, they were to reach out and touch the target's observed location on the table. Second, if the target did not seem reachable, they were to point to the location on the table where it appeared. Using this method, participants accuracy could be assessed with two measures (1) the accuracy with which participants could touch target locations within arm's reach using an open-loop action, and (2) the accuracy with which participants could distinguish between within- and beyond-reach targets and respond accordingly. The first measure assessed both *response selection*—participants decision to touch or point—and *response execution*—accuracy of open-loop action. The second measure assessed *response selection only*—judgment of perceived reachability as indicated by their decision to touch or point. (We did not—could not—measure the accuracy of pointing execution.)

While the first study was undertaken as an exploratory study of reaching actions, we expected to see two trends in the results. First, we expected that touching target locations would show an absence of over-estimation bias, just as blind walking does not exhibit the compression of space found in verbal judgments. In contrast, we expected that response selection – participants' decision to touch or point at the target location – *would* show the typical pattern of ~10% over-estimation. Studies two and three replicated the findings from Study 1, and extended both the expected and some unexpected findings.

2. Study 1

The first study was designed to establish the blind-reaching paradigm and to use it to determine whether reaching actions display the same over-estimation bias as verbal judgments of reaching ability.

2.1. Methods: Study 1

2.1.1. Participants

Twenty University of Virginia undergraduates (13 female) participated in this study in exchange for course credit.

2.1.2. Design

In this within-subjects repeated measures design, participants were shown a target at one of 9 distances grouped into 4 blocks, for a total of 36 experimental trials. Participants were tasked with choosing one of two responses based on whether they perceived the target to be within reach, in which case they blind reached to the target location, or out of reach, in which case they pointed.