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Perception of maximum stepping and leaping distance: Stepping affordances as a special case of leaping affordances

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ABSTRACT

Successfully performing everyday behaviors requires perceiving affordances—possibilities for behavior that depend on the fit between environmental properties and action capabilities. Whereas affordances for some behaviors are primarily constrained by relatively static geometric properties of the perceiver (non-launching behaviors such as stepping), others are additionally constrained by dynamic force production capabilities of the perceiver (launching behaviors such as leaping). This experiment used a transfer of calibration paradigm to investigate whether visual perception of launching and non-launching behaviors represent independent perception–action tasks. In particular, we investigated whether calibration of visual perception of maximum leaping distance transferred to visual perception of maximum stepping distance, and/or vice versa. The results showed that calibration of perception of maximum leaping distance transferred to perception of maximum stepping distance, suggesting that perception of launching and non-launching are not independent. Rather, perception of stepping affordances may be a special case of perception of leaping affordances.

1. Introduction

For most people, leaping over a puddle on a rainy day and stepping over an uneven piece of the sidewalk are routine activities. Whether or not these obstacles to locomotion can be stepped over or leaped over are examples of affordances—possibilities for behavior that are determined by a relationship between the features of the environment and the abilities of the person (Chemero, 2003; Gibson, 1979). Successfully performing any behavior requires successfully perceiving affordances. If the expanse of a puddle is too large in relation to the leg length and stepping ability of a person, then stepping over the puddle is not afforded. In this case, the person would need to leap over the puddle or walk around it. Misperceiving affordances could lead to attempting risky behaviors (e.g., attempting to step over a gap that is too wide or attempting to fit through a space that is too narrow) and result in accident or injury (see Comalli, Franchak, Char, & Adolph, 2013). Given that decisions about whether and how to perform a number of behaviors (e.g., stepping over, leaping over, or walking around an obstacle) occur throughout the course of ongoing everyday activities and in continually changing contexts (e.g., while running or walking, on a dry or wet surface), it is imperative that an individual be able to visually perceive affordances online and in real time.

1.1. Body-scaled and action-scaled affordances

In part, the action capabilities of a person are determined by his or her anthropometric properties such as height, shoulder width, leg length, and arm length. Accordingly, most previous research on affordances has focused on visual perception of possibilities for behaviors that depend on the relationships between these relatively static, geometric properties and reciprocal properties of the environment—so called body-scaled affordances. For example, visual perception of affordances for stair climbing is constrained, in part, by the relationship between the riser height of the step and the person's leg length. The boundary between stairs that are perceived to be climbable and those that are not (i.e., the perceptual boundary) occurs at a taller riser height for taller people than for shorter people. However, this boundary occurs at the same ratio of leg length to riser height regardless of leg length (Warren, 1984). Similar patterns of results have shown that relationships between anthropometric properties of the perceiver and reciprocal properties of the environment also constrain visual perception of affordances for other behaviors such as reaching (Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989; Wagman & Day, 2014), passing through apertures (Warren & Whang, 1987), and stepping over gaps in the support surface (Burton, 1992).

Importantly, the action capabilities of a person are also determined by a number of non-geometric factors including strength, flexibility, coordination, and balance. Accordingly, research has increasingly focused on visual perception of possibilities for behavior that depend

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on the relationships between these dynamic capabilities of the perceiver and reciprocal properties of the environment—so called action-scaled affordances (see Fajen, Riley, & Turvey, 2009). For example, visual perception of affordances for stair climbing is *also* constrained by the leg strength and flexibility of the person performing the stair-climbing task. The boundary between stairs that are perceived to be climbable and those that are not occurs at a taller riser height for younger adults (average age 23.5 years) than for older adults (average age 71.5 years), a difference likely due to differences in strength and flexibility between these two groups of participants (Konczak, Meeuwsen, & Cress, 1992). Similar patterns of results have shown that relationships between dynamic capabilities of the perceiver and reciprocal properties of the environment also constrain visual perception of affordances for behaviors such as jumping (Pepping & Li, 1997; Ramenzoni, Riley, Davis, Shockley, & Armstrong, 2008), standing on an inclined surface (Regia-Corte & Wagman, 2008), and running or walking under a horizontal barrier (Franchak, Celano, & Adolph, 2012; van der Meer, 1997).

It is worth noting that virtually all affordances are *both* body-scaled and action-scaled (Fajen et al., 2009). For example, a behavior such as vertical reaching while jumping is constrained, in part, by the participant's standing height and arm length and, in part, by his or her leg strength. Similarly, a behavior such as passing under a barrier is constrained by dynamic walking height (the continually changing height of the top of head as it rises and falls with each step cycle), mode of locomotion, and degree of motor control (Franchak et al., 2012; van der Meer, 1997, see Wagman & Malek, 2009).

As a result, the distinction between body-scaled and action scaled affordances is largely artificial. However, it is the case that whereas some behaviors are primarily constrained by static (geometric) properties of the perceiver (e.g., vertical reaching while standing), others are *additionally* constrained by dynamic (force production) capabilities of the perceiver (e.g., vertical reaching while jumping). Along these lines, Cole, Chan, Vereijken, and Adolph (2013) distinguish between launching and non-launching behaviors. Given that launching behaviors are constrained by dynamic capabilities in ways that non-launching behaviors are not, it is possible that these behaviors represent distinct or independent types of relationships between perceiver and environment. Subsequently, it is possible that visual perception of affordances for launching behaviors and perception of affordances for non-launching behaviors are independent perception-action tasks.

Two recent studies have provided indirect support for this hypothesis. Cole et al. (2013) investigated visual perception of affordances for different motor skills. Participants both perceived affordances for and performed a variety of behaviors such as leaping, swinging with the arms (on monkey bars), crawling, stepping, and (horizontal) reaching. Participants consistently underestimated their abilities to perform launching behaviors such as leaping and arm-swinging but did not underestimate their abilities to perform non-launching behaviors such as crawling, stepping, or reaching. Cole et al. (2013) concluded that, given the biomechanical and dynamical complexity of performing launching behaviors, visually perceiving affordances for such behaviors may be challenging in a way that doing so for non-launching behaviors is not.

Additionally, Weast, Shockley, and Riley (2011) investigated visual perception of affordances for sport-relevant behaviors (maximum standing vertical reach height and maximum jumping vertical reach height) and non sport-relevant behaviors (maximum sitting height) by both skilled athletes (experienced basketball players) and novices (non-basketball players). Both groups of participants perceived affordances for these behaviors for themselves (e.g., their own maximum standing reach height) and for another person (e.g., the other person's maximum standing reach height). The skilled athletes were more accurate than the novices at perceiving sport-relevant affordances for another person but only when the behavior in question was a launching behavior—maximum jumping reach height. They showed no advantage over novices when the behavior in question was a non-launching behavior—maximum standing reach height. The researchers speculated that extensive experience playing a particular sport (in this case, basketball) likely attuned the athletes to the kinematic patterns that provide information about sport-specific action-scaled affordances for other people.

1.2. Calibration and transfer of calibration

The relationship between action capabilities and environmental properties changes continually over both short and long time scales. In the span of a few seconds or minutes, movements of objects and fluctuating conditions can alter the environmental features relevant to performing a given behavior. Likewise, fluctuating levels of fatigue, increases or decreases in locomotion speed, or the addition or subtraction of carried loads can alter a person's ability to perform a given behavior. In the span of a few weeks, months, or years, developmental changes in strength, coordination, and balance as well as improvements in sport-specific athletic skills can similarly alter a person's ability to perform a given behavior. As a result, the affordances available to a particular person are continually evolving—affordances are dynamic (Fajen et al., 2009). The process by which perception of affordances is scaled to such continually evolving relationships between action capabilities and environmental properties is known as calibration (see Fajen, 2005; Withagen & Michaels, 2004, 2007).

Some research has shown that calibration of visual perception of affordances for a given behavior to action capabilities can occur following practice performing that behavior. For example, practice squeezing through narrow apertures is sufficient to calibrate perception of affordances for this behavior (Franchak, van der Zalm, & Adolph, 2010, see also Wagman, 2012). Other research has shown that calibration of visual perception of affordances for a given behavior can occur following practice performing a different (but related) behavior. For example, practice maneuvering a wheelchair through a hallway is sufficient to calibrate perception of whether the wheelchair can be maneuvered under a horizontal barrier (Stoffregen, Yan, Giveans, Flanagan, & Bardy, 2009).

Still other research has shown that calibration of perception of affordances for a given behavior can occur with practice perceiving that affordance (even without the opportunity to perform the behavior or a related behavior) so long as the perceiver can perform exploratory behaviors. For example, repeated experience perceiving whether a horizontal surface can be sat on is sufficient to calibrate perception of affordances for this behavior, so long as the perceiver is permitted to engage in postural sway while viewing the surface (Mark, Balliett, Craver, Douglas, & Fox, 1990; see Mark, 1987; Ramenzoni, Davis, Riley, & Shockley, 2010).

Regardless of how such calibration occurs, the transfer of calibration (or lack thereof) from one perception–action task to another is expected to reveal the degree to which those tasks are independent (see for example, Reiser, Pick, Pick, Ashmead, & Garing, 1995). If two tasks are dependent or are related in some way, then calibration of one ought to result in calibration of the other. That is, there will be a transfer of calibration. Conversely, if two perception–action tasks are independent or unrelated, then calibration of one ought not to result in calibration of the other. That is, there will be no transfer of calibration. This paradigm has been used to show that calibration of the relationship between walking and optic flow rate transfers to other locomotory behaviors such as sidestepping and crawling (Reiser et al., 1995; Withagen & Michaels, 2002) but not to behaviors such as throwing or turning in place (Bruggeman & Warren, 2010; Reiser et al., 1995; Witt, Proffitt, & Epstein, 2004).

1.3. The current experiment

The ability to step across an expanse depends primarily on the relationship between static geometric properties of the perceiver