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PERCEPTION OF MAXIMUM
STEPPING AND LEAPING
ABILITY

Brian M. Day

38 Pages

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To successfully perform everyday behaviors, people must be able to perceive affordances. Two general categories of affordances have been investigated: body-scaled affordances depend on geometric properties (e.g., arm length) and action-scaled affordances depend on dynamic properties (e.g., maximum running speed, body compressibility, etc.). The fact that these affordances depend on different kinds of relationships between animal and environment, suggests that body scaled affordances and action scaled affordances may be qualitatively different. We investigated this hypothesis by using a transfer of calibration paradigm. In particular, we investigated whether improvements in perception of maximum stepping distance (a body scaled affordance) transferred to perception of maximum leaping distance (an action scaled affordance), and vice versa. Participants reported maximum stepping and leaping distances in three different phases: a pre-test, practice session, and a post-test. In the practice session, half of the participants practiced performing a maximum distance step or leap, and half did not practice performing either behavior. The results showed that practice performing a maximum distance leap improved perception of maximum leaping distance and

maximum stepping distance. Practice performing a maximum distance step brought about no changes in perception of maximum leaping or stepping distance. Such results suggest that body-scaled affordances and action-scaled affordances may be related hierarchically. In other words, it is likely that all body scaled affordances are action scaled affordances, but not vice versa.

PERCEPTION OF MAXIMUM
STEPPING AND LEAPING
ABILITY

BRIAN M. DAY

A Thesis Submitted in Partial
Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

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2014

PERCEPTION OF MAXIMUM
STEPPING AND LEAPING
ABILITY

BRIAN M. DAY

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B.M.D

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CHAPTER I

INTRODUCTION

For a typical college student, leaping over a puddle on a rainy day and stepping over one uneven brick or piece of concrete on the way to class are routine activities. Performing these actions is not generally thought of as an impressive accomplishment, when in reality they highlight the complexity of the human perceptual-motor system. Successful navigation and locomotion in the world requires successful perception of affordances, which are the relations between the features of the environment and the characteristics of an organism that make a particular action possible (Chemero, 2003; Gibson, 1979). For example, if the expanse of a puddle is too large in relation to a person's leg length and stepping ability, then stepping over the puddle is not afforded. Instead, the person would need to leap over the puddle or walk around it. Successful action requires that perceivers know their action boundaries—the threshold that separates possible actions from impossible actions. Misperceiving action capabilities could lead to attempting risky behaviors (e.g., attempting to reach an object that is too far away or attempting to fit through a space that is too narrow) and result in accident or injury. Therefore, it is imperative for an individual to accurately perceive his or her action capabilities (Lessard, Linkenauger, Proffitt, 2009).

Body-scaled and Action-scaled Affordances

Fajen, Riley, and Turvey (2009) described two kinds of affordances: body-scaled affordances and action-scaled affordances. The majority of previous research has focused on body-scaled affordances—possibilities for behavior that depend primarily on static, geometric properties of the body (Fajen et al., 2009; Ramenzoni, Davis, Riley, & Shockley, 2010; Weast, Shockley, & Riley, 2011). Anthropometric properties like height, leg length, and arm length all have been shown to influence perception of body-scaled affordances. For example, in a study by Warren (1984), tall ($n = 12$, mean height = 189.8 cm) and short undergraduate men ($n = 12$, mean height = 163.7 cm) viewed sets of stairs with different riser heights and reported whether they could step up on each one. The results showed that the boundary between stairs that were perceived to be climbable and those that were not (i.e., the perceptual boundary) occurs at a taller riser height for tall participants than for short participants. However, this boundary occurred at the same ratio of leg length to riser height for both groups. Such results suggest that, in part, perception of affordances for stair climbing is determined by the relationship between the riser height of the step and the length of one's leg. In a related study by Warren and Whang (1987), undergraduate men with narrow shoulders ($n = 10$, mean shoulder width = 41.4 cm) and wide shoulders ($n = 10$, mean shoulder width = 47.7 cm) viewed doorways of different widths and reported whether they could pass through each one without turning their shoulders. The results showed that the boundary between apertures that are perceived to be pass-through-able and those that are not occurred at a wider doorway width for participants with wide shoulders than for participants with narrow

shoulders. Yet, this boundary occurred at the same ratio of doorway width to shoulder width for both groups.

However, a variety of non-static, dynamic factors also influence the performance of many behaviors. Action-scaled affordances are possibilities for behavior that depend on dynamic properties of the actor (i.e., force generation, acceleration, flexibility, etc.) (Fajen et al., 2009). A growing body of research has focused on perception of action-scaled affordances (e.g., Ramenzoni, Riley, Davis, Shockley, & Armstrong, 2008; Ramenzoni et al., 2010; Weast et al., 2011). For example, the ability to produce forces with the muscles of the upper and lower legs influences jumping ability, and this dynamic property is reflected in perception of maximum jumping heights (Pepping & Li, 1997; Ramenzoni et al., 2008). It is worth noting that most affordances are both body-scaled and action-scaled (Fajen et al., 2009). For example, an action such as reaching while jumping is constrained in part by the length of the actor's arm as well as by his or her force production abilities.

Building on the findings of Warren (1984), Konczak, Meeuwsen, and Cress (1992) investigated perception of stair climbability in young (mean age = 23 years) and older adults (mean age = 71 years). They found that the perceptual boundary occurred at both a smaller riser height and a smaller ratio of riser height to leg length for older participants than for younger participants. In addition, they found that for both groups of participants, leg flexibility and leg strength were better predictors of the perceptual boundary than leg length. Konczak et al. (1992) concluded that both an actor's geometric and dynamic properties constrain action capabilities and perception of affordances.

Similarly, van der Meer (1997) investigated the ability to pass under a barrier by both children and adults and found perception of this affordance differs developmentally. The participants in this study were normal adults, nursery school children, children with cerebral palsy, and infants (who had less than 6 weeks walking experience). Each participant approached (both by running and walking) and attempted to pass under a horizontal barrier set at different heights. The results suggested that dynamic variables such as mode of locomotion, degree of motor control and level of development are more influential on perception of whether a barrier can be passed under than are static, geometric variables such as standing height (see Franchak, Celano, & Adolph, 2012).

Given that action-scaled affordances reflect dynamic relationships and body-scaled affordances reflect static relationships, it is possible that they represent qualitatively different kinds of relationships between perceiver and environment. In other words, it is possible that body-scaled affordances are qualitatively different than action-scaled affordances, and subsequently that perception of body-scaled affordances is qualitatively different than perception of action-scaled affordances. The experiment reported here investigates this hypothesis.

Two recent studies have provided indirect support for this hypothesis. A study conducted by Cole, Chan, Vereijken, and Adolph (2013) investigated perception of affordances for different motor skills. In their study, participants (24 college aged men and women) both perceived affordances for and performed a variety of behaviors such as leaping, swinging with the arms (on monkey bars), crawling, stepping, and reaching. The results showed that participants consistently underestimated their abilities for leaping (a launching action with the legs) and for arm-swinging (a launching action using the arms).

However, participants did not underestimate their abilities to perform non-launching actions (i.e., crawling, stepping, and reaching). The researchers concluded that, given the biomechanical and dynamical complexity of performing launching behaviors, perceiving affordances for such behaviors may be challenging in a way that perceiving affordances for other (non-launching) behaviors is not.

Additionally, in a similar study by Weast, Shockley, and Riley (2011), participants were either experienced college-aged basketball players or non-basketball players. Both groups of participants perceived basketball-relevant and non-basketball relevant affordances for themselves and for another person. Specifically, participants judged maximum standing-reach height, maximum jumping reach height (the basketball-relevant affordances), and maximum sitting height (the non-basketball-relevant affordance) for themselves and for another person. Overall, the results showed that basketball players were more accurate than non-players at perceiving maximum jumping reach height for another person. Importantly, however, there was no difference between basketball players and non-basketball players in perceiving maximum standing reach for another person despite the fact that this is also a basketball-relevant affordance. The researchers speculated that athletes in a particular sport have developed an enhanced ability to perceive sport specific action-scaled affordances because experience with the sport has specifically attuned them to the (kinematic) information about these action-scaled affordances (see Higuchi, Murai, Kijima, Seya, Wagman & Imanaka, 2011).

Calibration and Transfer of Calibration

Both environmental features and action capabilities continually change over short and long time scales. For example, over short time scales, movements of objects and other people can alter environmental features relevant to performing a given behavior, and fatigue and injury can alter the action capabilities of an actor. Over long time scales, action capabilities can change due to developmental changes in strength, coordination, and balance as well as to practice performing sport-specific behaviors. As a result, the affordances available to a person are continually evolving. The process by which perception of affordances is scaled to the (changing) relationship between environmental features and action capabilities is known as calibration (e.g., Withagen & Michaels, 2004; 2007). Some research has shown that calibration of perception of affordances for a given behavior can occur following practice performing that behavior (Franchak, van der Zalm, & Adolph, 2010; Wagman, 2012) or a related behavior (Stoffregen, Yang, Giveans, Flanagan, & Bardy, 2009). However, other research has shown that calibration of perception of affordances for a given behavior can also occur following repeated experience perceiving affordances for that behavior (even without any explicit practice performing any behavior) (Mark, Balliett, Craver, Douglas, and Fox, 1990; Ramenzoni et al., 2010).

One method of investigating whether two perceptual-motor processes are independent (i.e., whether they are qualitatively different) is to use a transfer of calibration paradigm. This method is based on the transitive property: if two perceptual or motor skills share resources or are related in some way, then calibration of one skill will result in calibration of the other. That is, there will be a transfer of calibration.

Conversely, if two perceptual or motor skills are independent or unrelated, then calibration of one will not result in calibration of the other. That is, there will not be a transfer of calibration. This paradigm has been used to show that recalibration of perception of geometric object properties by a given limb transfers to a different limb (e.g., hand to foot, and vice versa; Stephen & Hajnal, 2011; Withagen & Michaels, 2004) and perception of geometric object properties by one perceptual modality transfers to another perceptual modality (e.g., hearing to touch, and vice versa, Wagman & Abney, 2012).

Current Study

The current experiment used a transfer of recalibration paradigm to investigate whether action-scaled and body-scaled affordances are qualitatively different. Specifically, it built on the findings of Cole et al. (2013) that launching behaviors (and perception of launching affordances) seem to be distinct from stepping behaviors (and perception of stepping affordances). Stepping across expanses of various lengths is a highly practiced, everyday task and depends, in large part, on static, geometric dimensions of the body. Leaping across expanses is a less practiced, less frequently required task and depends, in large part, on dynamic factors such as the force production abilities of the upper and lower leg muscles, balance, and coordination.

In the current experiment, participants (i.e., healthy college students) were randomly assigned to one of two practice tasks (Stepping or Leaping) and to one of two practice types (Perception or Action). The experiment consisted of three phases: a PreTest, practice, and a PostTest. In the PreTest, participants reported both perceived maximum stepping distance and perceived maximum leaping distance (on separate

blocks of trials). During the practice session, half of the participants reported perceived maximum stepping distance, and half reported perceived maximum leaping distance. Within each of these groups, half of the participants performed the (stepping or leaping) task after every trial, and the other half did not do so. The PostTest was identical to the PreTest.

Hypotheses

Based on the findings of Weast et al. (2011), Ramenzoni et al. (2010), and Cole et al. (2013) it was predicted that, in the PreTest, perception of maximum leaping distance would be less accurate than perception of maximum stepping distance. In addition, it was predicted that, in the practice session, practice performing a maximum distance step or leap would reduce this inaccuracy (i.e., improve perception of affordances) for the respective behaviors. Furthermore, it was predicted that in the PostTest improvements in perception would be behavior-specific. That is, practice performing a maximum distance step would lead to improvements in perception of maximum stepping distance but not in perception of maximum leaping distance, and practice performing a maximum distance leap would lead to improvements in perception of maximum leaping distance but not in perception of maximum stepping distance.

CHAPTER II

METHOD

Participants

64 undergraduate students from Illinois State University participated in this experiment. In the interest of participant safety, participants were required to be no heavier than 215 lbs. All participants received extra credit in their psychology courses in exchange for their participation. Participants were randomly assigned to one of two practice tasks (Stepping or Leaping) and to one of two practice types (Perception or Action). A power analysis was conducted using the G*Power program (Faul, Erdfelder, Lang, & Buchner, 2007). Effect sizes were estimated using significant main effects or interactions reported by Weast et al. (2011). The analysis indicated that a total of 48 subjects were needed for a medium effect size with power of 80% or higher.

Design

The experiment utilized a 2 (Phase: PreTest vs. PostTest) x 2 (Perception Task: Step vs. Leap) x 2 (Practice Task: Stepping vs. Leaping) x 2 (Practice Type: Perception vs. Action) mixed-design. Both Phase and Perception Task were within-subjects variables, and both Practice Task and Practice Type were between subjects-variables. During both the PreTest and PostTest, participants perceived maximum stepping and leaping distance during separate blocks of trials (Perception Task: Step vs. Leap). During the practice session, half of the participants practiced perceiving maximum stepping

distance, and half practiced perceiving maximum leaping distance (Practice Task: Stepping vs. Leaping). Within each of these groups, half of the participants practiced performing the behavior after each perceptual judgment, and half did not (Practice Task: Perception vs. Action).

Materials and Apparatus

A foam rubber mat approximately 430 cm long by 63 cm wide was used for participant safety. Additionally, a uniformly white 305 cm long wooden track was placed on one side of the foam rubber mat. The track (12 cm wide) consisted of two walls (7 cm tall) and a floor and contained a remote control car that was operated by the participant. The remote control car was a battery powered remote control car (19 cm long by 8 cm wide, manufactured by New Bright R/C) covered with black Velcro. A yellow horizontal marker was attached to the top of the car. Additionally, a tape measure affixed to the outside of the wooden track (not visible to the participant) was used to measure perceived and actual maximum stepping and leaping distances (see Figure 1). A scale was used to measure body weight, and a second tape measure attached to the wall was used to measure participant standing and sitting height.

(a)

(b)

(c)

Figure 1. (a) Participant view of the mat and report apparatus. (b) The remote control car used as the marker for participants' perceptual judgments. (c) Experimenter view of the experiment/report apparatus.

Procedure

Prior to the PreTest, participants were administered the Lateral Preference Inventory (Coren, 1993) to determine their preferred foot. Participants were instructed that stepping and leaping would occur with their preferred foot as the lead (and landing) foot. Additionally, participants were asked to be as accurate as possible when making perceptual judgments for both behaviors. Participants were instructed that their stepping and leaping abilities were not as important as their ability to accurately report these abilities. Participants were also informed that their actual stepping and leaping abilities would be measured at some point during the experiment. Next, the experimenter explained to the participant how to operate the remote control car. To ensure that participants were sufficiently able to control the car, participants were asked to use the remote control to align the car with a marker placed on the track 1 m from the participant. The marker was removed prior to the PreTest.

PreTest

Each participant stood at a tape mark at one end of the rubber mat. At the beginning of each trial, the remote control car was placed at either its nearest or farthest position (depending on whether the first trial was an ascending or descending trial, see below). The pretest consisted of two different types of Perception Tasks — step and leap (occurring on separate blocks of trials). On a trial in the step condition, the participant reported the maximum horizontal distance that they could step. A step was defined as follows: 1. The participant must step/lead with the preferred foot identified in the initial questionnaire. 2. One foot must be on the ground at all times. 3. The participant cannot lose their balance while performing the action. 4. The participant must be able to complete the step by bringing their trail foot (i.e., their non-preferred foot) in line with their lead foot. And 5. The participant could make no other movements like arm swinging or rocking.

On a trial in the leap condition, participants reported the maximum horizontal distance they could leap. A leap was defined as follows: 1. The participant must step/lead with the preferred foot identified in the initial questionnaire. 2. The participant must have both feet off the ground at some point. 3. The participant cannot lose their balance while performing the action. 4. The participant must be able to complete the leap by bringing their trail foot in line with their lead foot. And 5. The participant could make no other movements such as arm swinging or rocking.

In each condition, participants reported perceived maximum stepping and leaping distance by adjusting the distance of the marker placed on top of the remote control car. In all conditions, the participant was able to “fine tune” the distance of the marker on a

given trial until he or she was satisfied with its distance. After each trial, the participant moved the remote control car forward or backward to the starting location for the next trial.

All participants completed both the step and leap conditions. Participants completed twelve trials in each condition—blocks of six trials in the stepping condition were alternated with blocks of six trials in the leaping condition for a total of 12 trials in the PreTest.

The order of conditions was randomized across participants. Ascending trials (in which the marker was initially set at its closest position) and descending trials (in which the marker was initially set at farthest position) were alternated throughout, and the order of the sequence (i.e., whether the experiment began with an ascending or a descending trial) was counterbalanced across participants. At no point did the participant attempt to step or leap during the pretest.

Practice Session

After the pretest, each participant completed a practice session. The practice session consisted of 8 trials. As in the PreTest, ascending trials (in which the marker was initially set at its closest position) and descending trials (in which the marker was initially set at farthest position) were alternated throughout, and the order of the sequence (i.e., whether the experiment began with an ascending or a descending trial) was randomized. The task in these trials differed for participants in each of the practice conditions. Half of the participants practiced perceiving maximum stepping distance, and half practiced perceiving maximum leaping distance (Practice Task: Stepping vs. Leaping). Within

each of these groups, half of the participants practiced performing the behavior after each perceptual judgment, and half did not

(Practice Task: Perception vs. Action). Participants in the Perception Practice Condition performed the same task as in the PreTest. For participants in the Action Practice Condition, participants performed the same task as in the PreTest except that after the marker was set to his or her perceived maximum stepping distance, the experimenter removed the car from the track. The participant then handed the remote control to the experimenter and attempted to perform the behavior (maximum distance stepping or leaping, depending on condition). After performing this task, the experimenter placed the remote control car in the starting location for the next trial.

PostTest

The procedure for the posttest was identical to the procedure for the pretest.

After the conclusion of the experiment, the experimenter debriefed the participants and asked participants about their recent athletic and injury history. The experimenter also measured participants' actual maximum stepping distance and actual maximum leaping distance by having the participant perform each behavior twice. Additionally, the experimenter measured each participant's standing height, sitting height, and body weight.

CHAPTER III

RESULTS

Analysis of Perceived Maximum Stepping and Leaping Distance in the PreTest

To investigate what variables influence perception of maximum stepping and leaping distance (before any experience performing these tasks in the practice session), we analyzed perceived maximum stepping and leaping distances in the pretest only. Given that these analyses were performed on data from the pretest only, no differentiations were made between participants assigned to the different Practice Task or Practice Type Conditions. For the purposes of this set of analyses only, participants were sub-divided into groups based on median splits on leg length, maximum stepping distance, and maximum leaping distance, respectively. Dividing the participants in these ways created groups of participants who differed along dimensions relevant to performing a maximum distance stepping or leaping task. Namely, the short ($M = 92.6$ cm, $SD = 2.9$) cm and long leg length participants ($M = 102.3$ cm, $SD = 3.8$) differed in leg length, $t(62) = 11.4$, $p < .001$; the short ($M = 102.2$ cm, $SD = 8.0$) and long step ($M = 121.5$ cm, $SD = 7.1$ cm) participants differed in mean maximum stepping distance, $t(62) = 10.2$, $p < .001$; and the short ($M = 126.5$ cm, $SD = 9.7$) and long leap ($M = 152.5$, $SD = 10.4$ cm) participants differed in mean maximum leaping distance, $t(62) = 10.38$, $p < .001$. Notably, there was substantial, but not complete overlap in membership across groups. Twenty-one of thirty-two participants assigned to the short leg length group

were also assigned to both the short step and short leap groups (i.e., participants with short legs were usually, but not always, short steppers and short leapers). Eighteen of the thirty-two participants assigned to the long leg group were also assigned to both the long step and the long leap groups (i.e., participants with long legs were usually, but not always, long steppers and leapers).

Scaling of Perception in Participants with Different Leg Lengths

Mean perceived maximum stepping and leaping distances (raw values, in cm) were compared in a 2 (Leg Length: long vs. short) $\times$ 2 (Task: step vs. leap) analysis of variance (ANOVA). A main effect of Task [$F(1, 62) = 233.46, p < .001, \eta_p^2 = .79$] showed that mean perceived maximum leaping distance ($M = 143.3$ cm, $SD = 20.0$ cm) was longer than mean perceived maximum stepping distance ($M = 115.1$ cm, $SD = 16.4$ cm). A main effect of leg length [$F(1, 62) = 14.40, p < .001, \eta_p^2 = .19$] showed that perceived maximum stepping and leaping distances were longer for participants with long legs ($M = 136.5$ cm, $SD = 22.5$ cm) than for participants with short legs ($M = 122.0$ cm, $SD = 21.5$ cm). The interaction of leg length and task was not significant [$F < 1.00$].

Mean perceived maximum stepping and leaping distances were then divided by actual maximum stepping and leaping distances, respectively. Ratios equal to 1.0 indicate accurate perception of stepping or leaping ability, ratios less than 1.0 indicate underestimation, and ratios greater than 1.0 indicate overestimation. Mean ratio values were compared in a 2 (Leg Length: long vs. short) $\times$ 2 (Task: step vs. leap) ANOVA. The ANOVA revealed no significant effects (all F s < 1 , all p s $> .52$). The scaling of

perceived to actual maximum stepping or leaping distance did not differ for participants with different leg lengths.

Scaling of Perception in Participants with Different Stepping and Leaping Ability

Given that there was not complete overlap in membership across groups of participants, separate *t*-tests with Bonferroni corrections (rather than a single two-way ANOVA) were used to compare perceived maximum stepping distance (raw values, in cm) for short and long step participants and perceived maximum leaping distance for short and long leap participants, respectively. These *t*-tests revealed that mean perceived maximum stepping distance was longer for long step participants ($M = 123.4$ cm, $SD = 13.1$ cm) than for short step participants ($M = 106.9$ cm, $SD = 15.4$ cm), $t(62) = 4.61$, $p < .001$, and that mean perceived maximum leaping distance was longer for long leap participants ($M = 152.2$ cm, $SD = 19.9$ cm) than for short leap participants ($M = 134.4$, $SD = 15.9$ cm), $t(62) = 3.94$, $p < .001$.

Separate *t*-tests were also used to compare ratios of perceived-to-actual maximum stepping distance for short and long step participants and to compare ratios of perceived-to-actual maximum leaping distance for short and long leap participants, respectively. There was no difference between the mean ratio of perceived-to-actual maximum stepping distance for short step ($M = 1.04$ cm, $SD = 0.11$) and long step participants ($M = 1.02$, $SD = 0.10$), $t(62) = 1.09$, $p = .28$. However, ratios of perceived-to-actual maximum leaping distance were larger for short leap ($M = 1.06$ cm, $SD = 0.11$) participants than for long leap participants ($M = 1.00$ cm, $SD = 0.13$), $t(62) = 2.21$, $p < .05$. In particular, short leap participants overestimated their ability to leap—the ratio of perceived to actual

maximum leaping distance was greater than 1.0, $t(31) = 3.39, p < .005$. In contrast, the long leap participants did not overestimate their ability to leap—the mean ratio of perceived to actual maximum leaping distance was not different than 1.0, $t(31) = 0.015, p = .98$). The scaling of perceived to actual maximum stepping distance does not differ for participants with different stepping abilities. However, the scaling of perceived to actual maximum leaping does differ for participants with different leaping abilities. In particular, perception of maximum leaping distance is more accurate for long leap participants than for short leap participants.

Changes in Perceived-to-Actual-Maximum Stepping and Leaping Distance from PreTest to PostTest

To determine whether (and how) accuracy of perceived maximum stepping and leaping distance changed following the different kinds of practice, perceived maximum stepping and leaping distances in each condition in the PreTest and PostTest were divided by actual maximum stepping and leaping distances, respectively. Again, ratios equal to 1.0 indicate accurate perception of stepping or leaping ability, ratios less than 1.0 indicate underestimation, and ratios greater than 1.0 indicate overestimation. These values were compared in a 2 (Phase: PreTest vs. PostTest) $\times$ 2 (Perception Task: Step vs. Leap) $\times$ 2 (Practice Task: Stepping vs. Leaping) $\times$ 2 (Practice Type: Perception vs. Action) mixed-design ANOVA. This ANOVA revealed a significant three-way interaction of Phase $\times$ Practice Type $\times$ Practice Task [$F(1, 60) = 10.81, p < .005, \eta_p^2 = .15$] (See Figure 2). There were no other significant effects (all other F s $< 3.76, p$ s $> .05$).

Follow-up ANOVAs were conducted to further investigate the significant three-way interaction. In particular, separate 2 (Phase: PreTest vs. PostTest) $\times$ 2 (Practice Task: Stepping vs. Leaping) ANOVAs were performed on the data in the Perception Practice and Action Practice conditions, respectively. In the Perception Practice condition, there were no significant main effects or interactions (all other F s < 3.25 , p s $> .08$). In the Action Practice condition, there was a significant interaction of Phase $\times$ Practice Task [$F(1, 30) = 9.62$, $p < .01$, $\eta_p^2 = .24$] (See Figure 3).

Figure 2. Perceived-to-actual maximum stepping and leaping distances from Pre- to PostTest for Perception Practice and Action Practice groups. Error bars represent standard error of the mean.

Follow up paired-sample t-tests found that in the leaping practice condition there was a significant decrease in ratio values (i.e., an increase in accuracy) from PreTest ($M = 1.05$, $SD = .074$) to PostTest ($M = 1.02$, $SD = .055$; $t(15) = 2.39$, $p < .05$). In the stepping practice condition there was a marginal increase in ratio values (no change or a decrease in accuracy) from PreTest ($M = 1.04$, $SD = .087$) to PostTest ($M = 1.07$, $SD = .069$; $t(15) = 2.00$, $p = .063$).

In short, these results show that there were PostTest improvements in perception of both maximum leaping and maximum stepping distance but only following practice that included performing a maximum distance leap. There were no such improvements (in perception of either maximum leaping or maximum stepping distance) following practice that included only perceiving maximum leaping or stepping distance. There were also no such improvements (in perception of either maximum leaping or maximum stepping distance) following practice that included performing a maximum distance step (see Figure 3).

Figure 3. Perceived-to-actual maximum stepping and leaping distances from Pre- to Post Test by Practice Task within the Action Practice group. Error bars represent standard error of the mean.

Changes in Perceived-to-Actual-Maximum Stepping and Leaping Distance During Practice

To determine whether (and how) accuracy of perception of maximum stepping and leaping distances changed during the different kinds of practice, we analyzed ratios of perceived-to-actual maximum stepping and leaping distances for the first two and last two practice trials in a 2 (Practice Task: Stepping vs. Leaping) $\times$ 2 (Practice Type:

Perception vs. Action) $\times$ 2 (Trial: First Two vs. Last Two) mixed-design ANOVA. This ANOVA revealed a significant a significant three-way interaction of Trial $\times$ Practice Task $\times$ Practice Type [$F(1, 60) = 4.51, p < .05, \eta_p^2 = .07$]. Follow-up ANOVAs were conducted to further investigate the significant three-way interaction. In particular, separate 2 (Trial: First Two vs. Last Two) $\times$ 2 (Practice Task: Stepping vs. Leaping) ANOVAs were performed on the data in the Action Practice and Perception Practice conditions, respectively. In the Perception Practice condition, there were no significant main effects or interactions (all F s < 1). In the Action Practice condition, there was a significant two-way interaction of Trial $\times$ Practice Task [$F(1, 30) = 5.08, p < .05, \eta_p^2 = .15$]. Follow up t -tests showed a *decrease* in ratio when participants practiced leaping (first two trials: $M = 1.03, SD = .09$, last two trials: $M = 1.00, SD = .07; t(15) = 2.47, p < .05$) and no change when participants practiced stepping (first two trials: $M = 1.05, SD = .07$, last two trials: $M = 1.06, SD = .06; t(15) = 1.01, p = .33$).

Figure 4. Perceived-to-actual maximum stepping and leaping distances on the first two and last two practice trials in each condition. Error bars represent standard error of the mean.

CHAPTER IV

GENERAL DISCUSSION

Previous research has distinguished between two general categories of affordances: body-scaled affordances, which depend largely on geometric properties of the perceiver, and action-scaled affordances, which depend largely on the dynamic capabilities of the perceiver. The experiment reported here used a transfer of recalibration paradigm to investigate whether these two categories of affordances are qualitatively different. In particular, the experiment utilized this paradigm to investigate whether improvements in perception of a body-scaled affordance (maximum stepping distance) occur independently from improvements in perception of an action-scaled affordance (maximum leaping distance).

In a PreTest, practice session, and PostTest, participants reported maximum stepping and maximum leaping distances. In the practice session, half of the participants practiced perceiving maximum stepping distance, and half practiced perceiving maximum leaping distance. Within each of these groups, half of the participants practiced performing the behavior after each perceptual report and half did not. There were three main sets of findings. First, prior to any experience in the practice session, perceived maximum stepping and leaping distance scaled to actual maximum stepping and leaping distance in the same way for participants with different leg lengths.

Similarly, perception of maximum stepping distance scaled to actual maximum stepping distance in the same way for participants with different stepping abilities. In contrast, perception of maximum leaping distance scaled to actual maximum leaping distance in a way that depended on actual leaping ability. In other words, people with a given set of anthropometric properties were no better attuned to those properties than people with a different set of anthropometric properties, but people with different dynamic capabilities were differentially attuned to those capabilities. Second, in the practice session, practice performing a maximum distance leap improved perception of maximum leaping distance but practice performing a maximum distance step did not improve perception of maximum stepping distance. Third, there were PostTest improvements in perception of both maximum leaping and maximum stepping distance but only following practice that included performance of a maximum distance leap.

Evaluation of Hypotheses

Based on the results of previous research, the three hypotheses were made for the pattern of results in the current experiment. First, it was predicted that perception of maximum leaping distance would be less accurate than perception of maximum stepping distance. However, analysis of data from the pre-test only found no differences in the ratios of perceived-to actual maximum stepping distance and perceived-to-actual maximum leaping distance (see Figure 2).

Second, it was predicted that in the practice session, practice performing a given behavior (maximum distance step or leap) would improve perception of affordances for that behavior. However, analysis of data from the practice session found practice leaping

improved perception of maximum leaping distance, but practice stepping did not improve perception of maximum stepping distance (see Figure 2). Third, it was predicted that in the PostTest, improvements in perception would be behavior-specific. However, analysis of changes from the PreTest to the PostTest showed that practice performing a maximum distance leap improved both perception of maximum leaping distance and perception of maximum stepping distance. That is, recalibration of perception of maximum leaping distance transferred to perception of maximum stepping distance, but not vice versa.

Scaling of Perceived Maximum Distance Stepping and Leaping Prior to Practice

Data from the PreTest were analyzed to determine whether and how perceived maximum stepping and leaping distance scaled to properties of the perceiver before any experience performing the tasks in the practice session. Such analyses show that perception of maximum stepping and leaping distance scaled to actual stepping and leaping ability in the same way for participants with different leg lengths. Participants with long legs show longer mean perceived maximum stepping and leaping distances than participants with short legs, but there was no difference in the ratio of perceived-to-actual maximum stepping or leaping distance between these two groups of participants. These results are consistent with research showing that anthropometric properties constrain perception of affordances (Warren, 1984; Warren & Whang, 1987). In particular, populations of people who differ in a given anthropometric property (e.g., arm length, shoulder width, etc.) perceive different affordances for behaviors constrained by a given property but nonetheless show identical scaling of perception of affordances for that behavior to that property (Warren, 1984; Warren & Whang, 1987). For example,

participants who differ in arm length differ in perceived (and actual) maximum reaching distance but not in how perceived maximum reaching distance scales to reaching ability (e.g., Carello, Groszofsky, Reichel, Solomon, & Turvey, 1989). In other words, participants possessing a given set of anthropometric properties (e.g., long legs, long arms, or wide shoulders) are generally no better attuned to those properties (and how those properties influence action capabilities) than participants with a different set of anthropometric properties (e.g., short legs, short arms, or narrow shoulders).

In addition, the results showed that perception of maximum stepping distance scaled to actual maximum stepping distance in the same way for people who differ in stepping ability. Long steppers show longer mean perceived maximum stepping distance than shorter steppers, but there was no difference in the ratio of perceived-to-actual maximum stepping distance between these two groups of participants. Given that stepping ability is primarily constrained by an anthropometric property (i.e., leg length), these results are also consistent with research showing that anthropometric properties of the perceiver constrain perception of affordances (Warren, 1984; Warren & Whang, 1987). Just as participants who differ in leg length do not differ in how well attuned they are to this anthropometric property, participants who differ in stepping ability do not differ in how well attuned they are to this ability.

In contrast, perception of maximum leaping distance scaled to actual maximum leaping distance in different ways for people who differ in leaping ability. Long leapers show longer mean perceived maximum leaping distances *but smaller* ratios (i.e., closer to 1.0) of perceived-to-actual maximum leaping distance than short leapers. Given that leaping ability is constrained by dynamic properties (i.e., strength, flexibility,

coordination, balance) in addition to geometric properties, these results are consistent with research showing that such dynamic properties of the perceiver also constrain perception of affordances (Konczak et al., 1992; Malek & Wagman, 2008; Regia-Corte & Wagman, 2008). Populations of people who possess different dynamic capabilities (e.g., agility or a sport-specific skill) show different scaling of perception of affordances for a given behavior to that dynamic capability. For example, when running through narrow apertures, athletes with experience playing American football showed smaller magnitudes and later onset times of shoulder rotations than control athletes (Higuchi et al., 2011). In other words, participants possessing a given set of dynamic capabilities may be better attuned to those capabilities than participants with a different set of dynamic capabilities (Comalli, Franchak, Char, & Adolph, 2013; Franchak & Adolph, 2014). This may be especially so for individuals who have become more attuned to (kinematic) information about specific action-scaled affordances over the course of development or long-term practice (see Higuchi, et al., 2011; Weast et al., 2011).

Although these different patterns of attunement to geometric and dynamic properties do not necessarily provide evidence that body-scaled affordances and action-scaled affordances are (or are not) qualitatively different, they do seem to suggest that these two categories of affordances are not identical. The differential attunement to dynamic capabilities (but not geometric properties) may suggest that perception of action-scaled affordances in some ways supercedes that of body-scaled affordances (Comalli et al., 2014; Franchak & Adolph, 2014).

Changes in Perceived Maximum Stepping and Leaping Distance from Pre- to PostTest

The second main finding of the experiment was that there were PostTest improvements in perception of both maximum leaping and maximum stepping distance but only following practice that included performing maximum distance leaps. This finding is similar to a finding of Cole et al. (2013) that underestimation in launching ability was attenuated (even eliminated) following performance of launching behaviors. The current study found similar improvements in perception of maximum leaping distance (also a launching behavior) following practice leaping. Moreover, such improvements transferred to perception of maximum stepping distance. However, there were no such improvements in either perception of maximum stepping distance or perception of maximum leaping distance following practice performing maximum distance steps (a non launching behavior). In other words, improvements in perception of maximum leaping distance transferred to perception of maximum stepping distance, but not vice versa. Accordingly, the results show that improvements in perception of affordances for a given behavior transfer to unpracticed but related behaviors (Stoffregen et al., 2009). However, the results also show that practice performing a given behavior does not always lead to improvements in perception of affordances for that behavior (Mark et al., 1990). The finding that improvements in perception of maximum leaping distance (an action-scaled affordance) transferred to perception of maximum stepping distance (a body-scaled affordance), but not vice versa, suggests that body-scaled affordances and action-scaled affordances may be related hierarchically, in the sense that body-scaled affordances may be a special case of action-scaled affordances.

Is Body-scaled vs Action-Scaled Affordances a False Dichotomy?

Adolph and colleagues (Franchak & Adolph, 2013; Franchak, Celano, & Adolph, 2012) propose that all affordances (even ones that are typically considered to be purely or primarily body-scaled) are really action-scaled. For example, perception of whether a barrier can be passed under depends not on standing height, but rather on dynamic walking height – the continually changing height of the top of head as it rises and falls with each step cycle. In other words, performing any behavior involves moving the mass of the body and not merely the geometry of the body. Therefore, there may be no such thing as a truly body-scaled affordance. At best, a given affordance may be more or less dependent on anthropometric properties, but all affordances have some element of action scaling. In addition, static, geometric properties of the actor (such as leg length) may be better characterized as dynamic properties that merely change over longer time scales.

The distinction between body-scaled and action-scaled affordances may exist in practice (for the methodological convenience of the experimenter), but may not be theoretically meaningful. Even then, however, there may not be *qualitative* differences between the two categories. Rather, body-scaled affordances may be a special case of action-scaled affordances, in the same way that a stationary point of observation is a special case of a moving point of observation (Gibson, 1979). If this is the case, then movement of the perceiver (especially in the form of performing a behavior or a related behavior) may be more critical to recalibration of perception of affordances than previously thought.

Action capabilities depend on body size, morphology, and dynamic factors. In addition, action capabilities change over both short (e.g. seconds or minutes) and long

(e.g., weeks or months) time scales. Previous research has shown that experience moving the body is critical for recalibration of perception of affordance for a given behavior to (changed or new) action capabilities. However, such movement can be quite subtle and still be effective. For example, for behaviors that are largely constrained by geometric properties, postural sway itself is often sufficient for perceivers to recalibrate perception of affordances to (changed) action capabilities (Mark, 1987; Stoffregen et al., 2009). However, information about the dynamic capabilities of the body (e.g., flexibility) may not be (as readily) made available through such subtle movement. Under such circumstances, recalibrating perception to (changed) action capabilities may require more overt behaviors such as explicitly performing a given behavior or a related behavior. For example, leaping, crawling, or swinging over an expanse improves perception of affordances for each of these behaviors (Cole et al., 2013). To the extent that affordances for a given behavior are more or less body-scaled (and more or less action-scaled), there may be a difference in the experiences that are necessary and/or sufficient to bring about recalibration of perception of that affordance. Recalibration of perception of affordances that are primarily constrained by the anthropometric properties of the body may require practice *perceiving*, whereas recalibration of affordances that are primarily constrained by the dynamic capabilities of the affordances may requires practice *doing*.

Why Were Improvements in Perception Not Behavior-Specific?

The initial motivation for the experiment was to investigate a possible qualitative difference between (or, a possible independence of) body-scaled affordances and action-scaled affordances. This led to the hypothesis that PostTest improvements in perception

would be behavior-specific. That is, practice performing a maximum distance step would lead to improvements in perception of maximum stepping distance, and practice performing a maximum distance leap would lead to improvements in perception of maximum leaping distance but not in perception of maximum stepping distance. However, improvements in perception of affordances were not behavior specific. Instead, practice performing a maximum distance leap improved perception of both maximum stepping distance and maximum leaping distance, but practice performing a maximum distance step improved perception of neither maximum stepping distance nor maximum leaping distance. Again, such findings suggests that if there is any difference between body-scaled and action-scaled affordances, it is likely to be methodological and hierarchical.

The Effects of Practice

Contrary to what was hypothesized, during practice, performing a maximum distance leap improved perception of maximum leaping distance, but performing a maximum distance step did not improve perception of maximum stepping distance. This pattern is in accord with the pattern of results showing improvements in perception from Pre to PostTest for participants who practiced performing maximum distance leaps during the practice session. Convesely, participants in the Stepping Action condition showed no change in ratio during the practice session. This helps to account for the lack of improvements in perception from Pre to PostTest for the same group of participants.

Limitations of the Current Study

Previous research has shown that, in some cases, calibration of perception of affordances for a given behavior can occur following practice performing that behavior (Franchak et al., 2010; Wagman, 2012) or a related behavior (Stoffregen et al., 2009). However, other research has shown that calibration of perception of affordances for a given behavior can also occur following repeated experience perceiving affordances for that behavior (without any explicit practice performing any behavior) (Mark, 1987; Mark et al., 1990; Ramenzoni et al., 2010). Yet, the results of the current study were not necessarily consistent with either of these findings as no improvements were seen in the Perception condition, and practice stepping did not improve perception of stepping or of leaping.

Additionally, our results showed that participants continually overestimated their stepping and leaping abilities, even during the practice session and PostTest. The overestimation was possibly due to certain methodological issues. In the current experiment, the primary task of the participant was to report (rather than act on) maximum stepping and leaping distance. In addition, there was no actual gap in the support surface that required stepping or leaping across (cf. Burton, 1992; Jiang & Mark, 1994; Cole et al, 2013). Both of these features might have made the task somewhat artificial and therefore encouraged participants to adopt an analytic approach to what is generally a highly skilled perception-action process (Heft, 1993). Heft (1993) showed that perception of a maximum distance reach was more accurate when the perception of the affordance was embedded in a larger scale task and was not the focal point of the participants task. Conversely, when perception of the affordance was the focal point of

the task participants tended to overestimate their reaching ability. In the current experiment, the overestimation observed may have been due to adoption of an analytic approach to a perception-action task. In addition, participants might have been more conservative if there had been clearer consequences of overestimating their action capabilities (cf. Comalli, Franchak, Char, & Adolph, 2013; Wagman & Malek, 2007, 2009).

Another possible limitation of the the current study is the fact that participants were asked to report the absolute maximum distance they could step or leap. During routine everyday behaviors, people are rarely tasked with performing a given behavior at the limits of their ability. Instead, people would likely switch to a different mode of performing the same behavior before the absolute limit on the behavior is reached (Cordovil, Santos, Barreiros, 2012; Mark et al., 1997). Mark et al. (1997) distinguished between absolute and preferred critical boundaries, where an absolute critical boundary is the limit beyond which an action can no longer be completed successfully, and a preferred critical boundary is the point at which a person chooses to transition from one behavioral mode to another to accomplish a particular goal. It is somewhat artificial to ask participants to judge whether they can perform a particular action near its absolute critical boundary because actions are rarely performed near their absolute critical boundary. It may have been more appropriate to allow participants to select their own mode of action to achieve the goal.

Possibilities for Future Research

Future research should follow the suggestion of Heft (1993) of making the perception-action process a subsidiary task. Perhaps future research could incorporate a task that requires participants to move from one location to another with the subsidiary goal of traversing gaps of various sizes along the way. Experimenters could observe where the transition from stepping to leaping occurs in order to mark both the absolute critical boundaries for stepping and leaping and the preferred critical boundary for the two action modes. Future research may also investigate the effect of having participants take one or two steps toward the gap prior to reporting their maximum stepping distance. Previous research has shown that participants who initiate movement are more accurate at perceiving whether a ball is catchable or not than participants who remain stationary (Oudejans, Michaels, Bakker, & Dolne, 1996). It is possible that allowing participants to move toward the gap may allow for more accurate perception of maximum stepping or leaping distance.

Concluding Remarks

Previous research has distinguished between two general categories of affordances: body-scaled affordances, which depend on geometric properties, and action-scaled affordances, which depend largely on dynamic properties. The experiment reported here used a transfer of recalibration paradigm to investigate a possible qualitative difference between (perceiving) these types of affordances. The results showed that improvements in perception of maximum leaping distance transfers to perception of maximum stepping

distance but not vice versa. Such results suggest that the body-scaled affordances and action-scaled affordances are likely to be hierarchially related.

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