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

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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.

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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, Grossofsly, 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
on the relationships between these dynamic capabilities of the perceiv-
er and reciprocal properties of the environment—so called action-scaled
affordances (see Fajen, Riley, & Turvey, 2009). For example, visual per-
ception 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
(Régia-Corte & Wageman, 2008), and running or walking under a hori-
zontal 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 par-
ticipant’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 Wageman & 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) proper-
ties 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 behav-
iors 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 maxi-
mum 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 subtrac-
tion 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

Some research has shown that calibration of visual perception of
affordances for a given behavior to action capabilities can occur follow-
ing 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 Wageman, 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 hori-
zontal surface can be sat on is sufficient to calibrate perception of
affordances for this behavior, so long as the perceiver is permitted to en-
gage in postural sway while viewing the surface (Mark, Balliott, 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 ex-
ample, Reiser, Pick, Pick, Ashmead, & Garing, 1995). If two tasks are de-
pendent 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 cali-
bration. 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, Profitt, &
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
(such as leg length) and reciprocal properties of the environment (i.e., width of the expanse). The ability to leap across an expanse additionally depends on the relationship between dynamic capabilities of the perceiver (such as the strength the leg muscles, balance, and coordination) and reciprocal properties of the environment.

We investigated whether calibration of visual perception of maximum leaping distance transferred to visual perception of maximum stepping distance, and/or vice versa. We expected that the results would shed light on whether perception of affordances for launching and non-launching behaviors are independent perception–action tasks. As a result, we expected that the results would also shed light on the degree to which the perception of affordances for body-scaled and action-scaled behaviors are independent perception–action tasks.

Participants reported visually perceived maximum stepping and leaping distance in a Pre-test, Practice Session, and Post-test. 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 respective behavior after every trial (stepping or leaping), and the other half did not do so (see Fig. 1).

We had three main hypotheses. First, in the Pre-test, perceptions of maximum stepping distance and maximum leaping distance would reflect stepping and leaping ability, respectively. Second, in the Practice Session, practice performing a maximum distance step or leap would serve to calibrate perception of affordances for these respective behaviors. Third, the degree to which these two perception–action tasks are independent would determine the degree to which calibration of perception of affordances for stepping transfers to perception of affordances for leaping, and/or vice versa. Specifically, if perception of maximum stepping and leaping distance are independent or unrelated perception–action tasks, then calibration of perception of affordances would be behavior-specific, and there will be no transfer of calibration. Alternatively, if perception of maximum stepping and leaping distance represent dependent or related perception–action tasks, then calibration of perception of affordances would not be behavior-specific, and there would be transfer of calibration.

2. Method

2.1. Participants

Sixty-four undergraduate students from Illinois State University participated in this experiment. In the interest of participant safety, participants were required to be no heavier than 97.5 kg (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 task conditions (stepping or leaping) and to one of two practice type conditions (perception or action). The protocol used in this experiment was approved by the Institutional Review Board at Illinois State University in accordance with the Declaration of Helsinki.

2.2. Design

The experiment utilized a 2 (Phase: Pre-test vs. Post-test) × 2 (Perception Task: Step vs. Leap) × 2 (Practice Type: Perception vs. Action) mixed-design. Both Phase and Perception Task were within-participants variables, and both Practice Task and Practice Type were between-participants variables (see Fig. 1). During both the Pre-test and Post-test, participants reported visually perceived maximum stepping and leaping distances 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 performed the respective behavior after each trial, and half did not (Practice Task: Perception vs. Action) (see Fig. 1).

2.3. Materials and apparatus

A thin black foam rubber mat (approximately 430 cm long × 60 cm wide) was used for participant safety. A yellow tape mark indicated where each participant should stand on every trial. A white 305 cm long × 12 cm wide long wooden track was located to the right of the mat. The track consisted of a floor and two walls (7 cm tall) (see Fig. 2, top). The participant used a battery powered remote control car (approximately 19 cm long × 8 cm wide, New Bright R/C, Hong Kong) to report perceived maximum stepping and leaping distance on every trial. The top of the car was covered with black Velcro and a yellow horizontal line (see Fig. 2, top). A tape measure affixed to the outside wall of the wooden track (not visible to the participant) was used to measure perceived and actual maximum stepping and leaping distances. A digital scale was used to measure body weight, and a second tape measure attached to a wall was used to measure participant standing and sitting height.

2.4. Procedure

Each participant was administered the relevant portions of the Lateral Preference Inventory (Coren, 1993) to determine his or her preferred foot. The participant was instructed that stepping and leaping would occur with the preferred foot as the lead (and landing) foot. Each participant was also informed that his or her stepping and leaping abilities would be measured at the conclusion of the experiment. In an attempt to reduce possible sources of variance in the pre-test (e.g., intentional or unintentional response bias on the part of the participant), participants were informed that accuracy in perception was more important than actual stepping and leaping ability, per se. Next, the experimenter explained how to operate the remote control car. To ensure that the participant was sufficiently able to do so, he or she was instructed to use the remote control to align the marker on the car with a target on the track located 1 m from the participant. The target was removed prior to the Pre-test.

2.4.1. Pre-test

Each participant stood just behind the tape mark on the rubber mat. At the beginning of each trial, the 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 Pre-test consisted of two 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 he or she could step. A step was defined as follows: 1. The participant must lead with the preferred foot (as identified by the Lateral Preference Inventory). 2. One foot must be on the floor at all times while performing the behavior. 3. The participant cannot lose his or her balance while performing the behavior. 4. The participant must be able to complete the step by bringing his or her trail foot (i.e., the non-preferred foot) in line with lead foot. And 5. The participant could make no other movements like arm swinging or rocking.

On a trial in the Leap condition, the participant reported the maximum horizontal distance he or she could leap. A leap was defined as follows: 1. The participant must lead with the preferred foot. 2. The participant must have both feet off of the floor while performing the behavior. 3. The participant cannot lose his or her balance while performing the behavior. 4. The participant must be able to complete the leap by bringing the trail foot in line with the lead foot. And 5. The participant could make no other movements such as arm swinging or rocking.

On a given trial in each condition, the participant used the remote control to adjust the distance of the marker on top of the car such that it corresponded to his or her perceived maximum stepping or leaping distance. He or she was able to take as long as necessary to “fine tune” the distance of the marker on a given trial. After the completion of
each trial, the participant used the remote control to move the car forward or backward to the starting location for the next trial.

Each participant completed both the Step and Leap conditions. Participants completed six trials in each condition. Conditions were blocked, and order of conditions was counterbalanced across participants. Ascending trials (in which the marker was initially set at the closest position to the participant) and descending trials (in which the marker was initially set at the farthest position from the participant) were alternated over the twelve trials of the Pre-test (and the sequence continued through the Practice Session and Post-Test). Whether the first trial in the sequence was an ascending or descending trial was counterbalanced across participants. At no point did the participant attempt to step or leap during the Pre-test.

2.4.2. Practice session

After the Pre-test, each participant completed a Practice Session consisting of eight trials. The task differed for participants in different conditions.

Half of the participants practiced perceiving maximum stepping distance, and half practiced perceiving maximum leaping distance (Practice Task: Stepping vs. Leaping).

Participants assigned to the Stepping Practice Task \(n = 32\) performed the same task as in the Step condition in the Pre-test. That is, they stood behind the tape mark and reported perceived maximum stepping distance by adjusting the distance of the marker (as described above). Participants assigned to the Leaping Practice Task \(n = 32\) performed the same task as in the Leap condition in the Pre-test. That is, they stood behind the tape mark and reported perceived maximum leaping distance by adjusting the distance of the marker (as described above) (see Figs. 1 and 2).

Within each of these groups, half of the participants performed the respective behavior after each trial, and half did not (Practice Task: Perception vs. Action). In the Perception Action condition \(n = 32, 16\) from Stepping Practice and 16 from Leaping Practice), after the participant set the marker to his or her perceived maximum stepping or leaping distance (depending on Practice Task condition), the experimenter removed the car from the track, and the participant handed the remote control to the experimenter. The participant then attempted to perform either a maximum distance step or leap (again, depending on Practice Task condition). In the Stepping Practice condition (again, \(n = 32, 16\) from Stepping Practice and 16 from Leaping Practice), the trial concluded as soon as the participant set the marker to his or her perceived maximum stepping or leaping distance (depending on condition) (see Fig. 1).

Participants did not attempt to perform either a maximum distance step or maximum distance leap (regardless of Practice Task condition). As indicated in Section 2.4.1, ascending trials and descending trials were alternated throughout.

2.4.3. Post-test

The procedure for the Post-test was identical to the procedure for the Pre-test (see Fig. 1). After the conclusion of the twelve trials of the Post-test, the experimenter debriefed each participant and asked about his or her athletic and injury history. The experimenter also measured each participant’s actual maximum stepping and leaping distance. Each participant performed both of these behaviors twice. Additionally, the experimenter measured each participant’s standing height, sitting height, and body weight.

3. Results

3.1. Scaling of perceived maximum stepping and leaping distance to stepping and leaping ability

To investigate whether perception of maximum stepping and leaping distance scaled to stepping and leaping ability, respectively, before experience performing these tasks in the Practice Session, we first analyzed data from the Pre-test only. Given that these analyses were performed on data from the Pre-test, no differentiations were made between participants assigned to the different Practice Task or Practice Type conditions. In addition, for the purposes of this set of analyses only, participants were sub-divided into groups based on separate median splits on maximum stepping distance and maximum leaping distance, respectively. The Short \((M = 102.2\, \text{cm}, SD = 8.0)\) and Long Step \((M = 121.5\, \text{cm}, SD = 7.1)\) participants differed in mean maximum stepping distance, \(t(62) = 10.2, p < .001; \text{Cohen’s } d_t = 2.56\) (see Lakens, 2013); and the Short \((M = 126.5\, \text{cm}, SD = 9.7)\) and Long Leap \((M = 152.5, SD = 10.4)\) participants differed in mean maximum leaping distance, \(t(62) = 10.38, p < .001; \text{Cohen’s } d_t = 2.60\). There was substantial, but not complete overlap in membership among groups. Twenty-five of thirty-two participants assigned to the short step group were assigned to the short leap group. That is, participants who were short steppers were usually, but not always, short leapers. Likewise, participants who were long steppers were usually, but not always, long leapers.

Given that there was not complete overlap in membership across groups of participants, separate t-tests with Bonferroni corrections (rather than a single ANOVA) were used to compare perceived maximum stepping distance for Short and Long Step participants and perceived maximum leaping distance for Short and Long Leap participants, respectively. Mean perceived maximum stepping distance was longer for Long Step participants \((M = 123.4\, \text{cm}, SD = 13.1)\) than for Short Step participants \((M = 106.9\, \text{cm}, SD = 15.4)\), \(t(62) = 4.61, p < .001; \text{Cohen’s } d_t = 1.15\); and mean perceived maximum leaping distance was longer for Long Leap participants \((M = 121.5\, \text{cm}, SD = 19.9)\) than for Short Leap participants \((M = 134.4, SD = 15.9)\), \(t(62) = 3.94, p < .001; \text{Cohen’s } d_t = 0.98\).

Next, mean perceived maximum stepping and leaping distances were divided by mean actual maximum stepping and leaping distances, respectively. Ratios equal to 1.0 indicate accurate perception, ratios less than 1.0 indicate underestimation, and ratios greater than 1.0 indicate overestimation. There was no difference in perceived-to-actual maximum stepping distance for Short Step \((M = 1.04\, \text{cm}, SD = 0.11)\) and Long Step participants \((M = 1.02, SD = 0.10)\), \(t(62) = 1.09, p = .28; \text{Cohen’s } d_t = 0.27\). However, ratios of perceived-to-actual maximum leaping distance were larger for Short Leap \((M = 1.06\, \text{cm}, SD = 0.11)\) participants than for Long Leap participants \((M = 1.00, SD = 0.13)\), \(t(62) = 2.21, p < .05; \text{Cohen’s } d_t = 0.55\). Overall, the results from the Pre-test show that perception of maximum stepping distance scaled to stepping ability in the same way regardless of stepping ability, but perception of maximum leaping ability scaled to leaping ability in different ways depending on leaping ability.

3.2. Changes in perceived-to-actual maximum stepping and leaping distance during practice

To investigate the calibration (or lack thereof) of perception of maximum stepping and leaping distances during the different practice conditions, we compared ratios of perceived-to-actual maximum stepping and leaping distances for the mean of the first two practice trials and the mean of the last two practice trials in a 2 (Practice Task: Stepping vs. Leaping) × 2 (Practice Type: Perception vs. Action) × 2 (Practice Trials: First Two vs. Last Two) mixed-design ANOVA. This ANOVA revealed a significant three-way interaction of Practice Trials × Practice Task × Practice Type \(F(1, 60) = 4.51, p < .05, \eta_p^2 = .07\) (see Fig. 3).

Follow-up ANOVAs were conducted to further investigate the significant three-way interaction. In particular, separate 2 (Practice Trials: First Two vs. Last Two) × 2 (Practice Task: Stepping vs. Leaping) mixed-design 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 \(Fs < 1\)). In the Action Practice condition, there was a significant interaction of Practice Trials × Practice Task \(F(1, 30) = 5.08, p < .05\).
Follow up $t$-tests showed a decrease in ratio (an increase in accuracy) when participants practiced leaping (first two trials: $M = 1.03, SD = .09$, last two trials: $M = 1.00, SD = .07$; $t(15) = 2.47, p < .05$; Cohen's $d_{av} = 0.33$, see Lakens, 2013) and no change when participants practiced stepping (first two trials: $M = 1.05, SD = .07$, last two trials: $M = 1.06, SD = .06$; $t(15) = 1.01, p = .33$; Cohen's $d_{av} = 0.24$) (see Fig. 3).

Overall, the results from the Practice Session show that, in the context of the experimental conditions of the current experiment, practice perceiving was not sufficient to calibrate perception of maximum stepping distance or perception of maximum leaping distance. Practice performing a stepping task was also not sufficient to calibrate perception of maximum stepping distance. However, practice performing a leaping task was sufficient to calibrate perception of maximum leaping distance.

### 3.3. Changes in calibration from Pre-test to Post-test

To investigate changes in perception of maximum stepping and leaping distances following the different kinds of practice, we compared ratios of perceived-to-actual maximum stepping and leaping distances from the Pre-test and Post-test in a $2 \times 2 \times 2 \times 2$ (Phase: Pre-test vs. Post-test) $\times$ (Perception Task: Step vs. Leap) $\times$ (Practice Task: Stepping vs. Leaping) $\times$ (Practice Type: Perception vs. Action) mixed-design ANOVA. This ANOVA revealed a significant interaction of Phase $\times$ Practice Type $\times$ Practice Task $[F(1, 60) = 10.81, p < .005, \eta^2_p = .15]$ (see Fig. 4). 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 $2 \times 2$ (Phase: Pre-test vs. Post-test) $\times$ 2 (Practice Task: Stepping vs. Leaping) mixed-design 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 $[F(1, 30) = 9.14, p < .01, \eta^2_p = .24]$ (see Fig. 4 bottom, and Fig. 5).

Follow up paired-sample $t$-tests found that, in the Leaping Practice condition there was a significant decrease in ratio values (i.e., either no change or a decrease in accuracy) from Pre-test ($M = 1.04, SD = .087$) to Post-test ($M = 1.07, SD = .069$; $t(15) = 2.00, p = .063$; Cohen’s $d_{av} = 0.37$) (see Lakens, 2013) (see Fig. 5).

Overall, the results from these analyses show that there were Post-test improvements in perception of both maximum leaping and maximum stepping distance but only following practice performing a maximum distance leap. Moreover, under such circumstances, there was no difference in improvement of perception for these two tasks. There were no such improvements (in perception of either maximum leaping or maximum stepping distance) following practice performing a maximum distance step. Moreover, there were no improvements in perception of either maximum leaping or maximum stepping distance following practice perceiving maximum leaping or stepping distance.
In short, calibration of visual perception of maximum leaping distance transferred to perception of maximum stepping distance.

4. Discussion

Previous research has distinguished between body-scaled and action-scaled affordances (see Fajen et al., 2009). While this distinction is largely artificial, there are some behaviors that are primarily constrained by static (geometric) properties of the perceiver and others that are additionally constrained by dynamic (force production) capabilities of the perceiver. Along these lines, there is reason to suspect that launching behaviors (such as swinging, leaping) and non-launching 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 (see Cole et al., 2013; Weast et al., 2011). We used a transfer of calibration paradigm to investigate this hypothesis. In particular, we investigated whether calibration of visual perception of maximum leaping distance transfers to visual perception of maximum stepping distance, and/or vice versa.

There were three main sets of findings. First, in the Pre-test, visually perceived maximum stepping distance scaled to actual maximum stepping distance in the same way regardless of stepping ability. In contrast, visually perceived maximum leaping distance scaled to actual maximum leaping distance in a way that depended on leaping ability such that people with different leaping abilities were differentattuned to such abilities.

Second, during the Practice Session, performing a maximum distance leap was sufficient to calibrate visual perception of maximum leaping distance, but performing a maximum distance step was not sufficient to calibrate visual perception of maximum stepping distance. Practice perceiving maximum stepping or leaping distance was not sufficient to calibrate either.

Third, in the Post-test, there was calibration of both perception of maximum leaping distance and perception of maximum stepping distance but only following practice performing a maximum distance leap. In other words, calibration of perception of maximum leaping distance transferred to perception of maximum stepping distance. These three findings and their implications for an understanding of the relationship between visual perception of body-scaled and action-scaled affordances will be discussed in turn.

4.1. Scaling of perceived maximum stepping and leaping distance to ability

Data from the Pre-test were analyzed to determine whether (and how) visually perceived maximum stepping and leaping distances scaled to stepping and leaping ability, respectively. Such analyses showed that Long Step participants show longer perceived and actual maximum stepping distances than Short Step participants. However, there was no difference in the ratio of perceived-to-actual maximum stepping distance between these two groups. In other words, visual perception of maximum stepping distance scaled to actual stepping ability in the same way for participants with different stepping abilities. To the extent that stepping ability is constrained by anthropometric properties, these results are consistent with research showing that populations of people who differ in a particular anthropometric property perceive different affordances for a behavior constrained by that property but show identical scaling of perception of affordances to that property. 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 arm length (e.g., Carello et al., 1989). In other words, people possessing a given set of anthropometric properties (e.g., long legs, long arms, or wide shoulders) are no better attuned to those properties and how those properties influence action capabilities than people possessing a different set of anthropometric properties (e.g., short legs, short arms, or narrow shoulders).

However, there was a different pattern for people who differed in leaping ability. Visual perception of maximum leaping distance scaled to actual maximum leaping distance in different ways for people with different leaping abilities. Specifically, Long Leap participants showed longer mean perceived maximum stepping distance but smaller ratios (i.e., closer to 1.0) of perceived-to-actual maximum stepping distance than Short Leap participants. Such results suggest that people who differ in leaping ability differ in attunement to that ability. To the extent that leaping ability is constrained by dynamic capabilities (e.g., lower body strength required to produce and absorb forces, lower body flexibility required to create separation between the trail foot and the lead foot, balance required to land on the lead foot only, etc.), these results are consistent with research showing that people who differ in a particular dynamic capability (e.g., a sport-specific skill) show differential attunement to such capabilities (e.g., Comalli et al., 2013; Konczak et al., 1992; Regia-Corte & Wagman, 2008). For example, when running between tackling dummies, athletes with experience playing American football showed smaller and more delayed shoulder rotations than control athletes (Higuchi et al., 2011; see also Franchak & Adolph, 2014). In such cases, it is likely that action capabilities and visual perception of affordances calibrate simultaneously as the person becomes increasingly attuned to perceptual information specifying affordances for performing a particular behavior over the course of development or long-term practice (Fajen et al., 2009; Weast et al., 2011).

In summary, the results from the Pre-test show that whereas people who differ in stepping ability were not differently attuned to this ability, people who differ in leaping ability were differently attuned to this ability. Although different patterns of attunement to these abilities does not necessarily serve as evidence that perception of maximum stepping and leaping distance are (or are not) independent perception–action tasks, such results do seem to suggest that visual perception of affordances for these behaviors do not constitute identical perception–action tasks. While it is the case that virtually all affordances are both body-scaled and action-scaled, some behaviors are primarily constrained by anthropometric properties and others are additionally constrained by force production capabilities. Differential attunement to leaping ability...
but not stepping suggests that, in such cases, perception of action-scaled affordances in some ways supersedes that of body-scaled affordances (see Comalli et al., 2013; Franchak & Adolph, 2014). In other words, perception of body-scaled affordances may be a special case of perception of action-scaled affordances.

4.2. The effects of practice on perception of maximum stepping and leaping distance

During practice, performing a maximum distance leap calibrated perception of maximum leaping distance, but performing a maximum distance step did not calibrate perception of maximum stepping distance (see Fig. 3). The lack of calibration of perception of maximum stepping distance with practice performing a maximum distance step was inconsistent with our hypotheses. However, this finding is generally consistent with research showing that explicitly performing a behavior that is primarily constrained by an anthropometric property does not necessarily calibrate visual perception of affordances for that behavior. For example, practice performing a sitting task was not sufficient to calibrate visual perception of maximum sitting height (Mark et al., 1990), and extensive practice maneuvering a wheelchair through a doorway was not sufficient to (completely) calibrate visual perception of affordances for this behavior (Higuchi, Takada, Matsuura, & Imanaka, 2004). It is possible that calibration would have occurred with additional practice performing these behaviors or, more likely, with more extensive opportunities to engage in exploratory behaviors (e.g., walking around between trials), even without practicing a maximum distance step or leap (see Mark et al., 1990; Ramenzoni et al., 2008; Stoffregen et al., 2009). This may be a topic for future research.

In contrast, the calibration of perception of maximum leaping distance with practice performing a maximum distance leap was consistent with our hypotheses. Moreover, it is also consistent with research showing that explicitly performing a behavior that is primarily constrained by a dynamic capability can be sufficient to calibrate visual perception of affordances for that behavior. For example, practice squeezing through a narrow doorway was sufficient to calibrate visual perception of affordances for this behavior (Higuchi, Takada, Matsuura, & Imanaka, 2014; see also Stoffregen et al., 2009), and practice performing launching behaviors was sufficient to calibrate visual perception of affordances for such behaviors (Cole et al., 2013). Still, the relationship between practice performing a given behavior and calibration of perception of affordances for that behavior remains somewhat unclear (see Franchak et al., 2010; Higuchi, 2013; Yasuda et al., 2014). For our purposes, however, the different effects of practice on perception of maximum stepping and leaping distance, respectively, provides additional evidence that perception of affordances for these behaviors are not identical perception–action tasks and that perception of body-scaled affordances may be a special case of perception of action-scaled affordances.

Practice perceiving affordances for a maximum distance step or leap did not calibrate perception of affordances for these behaviors. Such findings are inconsistent with research showing that practice perceiving affordances for a given behavior can calibrate perception of affordances for that behavior if such practice provides sufficient opportunity to explore the structured energy array of relevance (Ramenzoni et al., 2010; Yu & Stoffregen, 2012). For example, practice perceiving whether a horizontal surface can be sat on serves to calibrate perception of affordances for this behavior if the perceiver is permitted to engage in postural sway while viewing the surface (Mark et al., 1990). Postural sway was not restricted in the Practice Session of the experiment reported here except that participants were to stand behind the yellow tape mark while performing the perceptual task. Again, it is possible that calibration would have occurred with a more extensive opportunity to perform exploratory behaviors. This may be a topic for future research.

4.3. Transfer of calibration of perception of maximum leaping distance

In the Post-test, there was calibration of both perception of maximum stepping distance and perception of maximum leaping distance but only following practice performing a maximum distance step. That is, calibration of perception of maximum leaping distance transferred to perception of maximum stepping distance (see Fig. 4). Given that perception of maximum stepping distance did not calibrate during practice, it was not possible to evaluate whether calibration of perception transferred in the other direction (i.e., from perception of maximum stepping distance to perception of maximum leaping distance). Still, the finding that there was unidirectional transfer of calibration from perception of maximum leaping distance to perception of maximum stepping distance is consistent with our hypotheses and, to some extent, serves to elucidate the relationship between these two perception–action tasks. As discussed in Section 1.2, 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. The unidirectional transfer of calibration observed here provides evidence that perception of maximum leaping distance and perception of maximum stepping distance are related but not identical. More generally, such findings are also consistent with the proposal that perception of body-scaled affordances is a special case of perception of action-scaled affordances. A more complete test of the transfer of calibration from perception of maximum stepping distance to perception of maximum leaping distance will require conditions under which perception of maximum stepping distance improves with practice. This may also be a topic of future research.

4.4. Body-scaled vs. action-scaled affordances is a false dichotomy

The transfer of calibration of perception of maximum leaping distance to perception of maximum stepping distance suggests that visual perception of these two affordances are related perception–action tasks. However, the differential patterns of attunement observed in the Pre-test and the differential calibration of perception with practice performing these tasks observed in the Practice Session suggest that these perception–action tasks are not identical. The relevant question, then, is what is the relationship between perception of these two affordances? And, more generally, what is the relationship between perception of body-scaled and action-scaled affordances? The pattern of results across all three phases of the experiment suggests that perception of body-scaled affordances and perception of action-scaled affordances may be related hierarchically. That is, body-scaled affordances may be special cases of action-scaled affordances in which particular dynamic capabilities of the perceiver are not (as) relevant to performing the intended behavior. Perception of body-scaled affordances may be a special case of perception of action-scaled affordances in the same way that a perception from a stationary point of observation is a special case of perception from a moving point of observation (Gibson, 1979).

Performing any behavior involves moving the mass of the body together with the geometry of the body. At best, a given affordance may be more or less dependent on anthropometric properties, but all affordances are dependent on dynamic capabilities. Moreover, so-called static properties of the actor (such as leg length, arm length, and shoulder width) may be better characterized as dynamic properties that merely change over much longer time scales. For example, perception of whether a barrier can be passed under depends not on standing height per se, but rather on dynamic walking height—the continually changing height of the top of head as it rises and falls with each step cycle (Franchak et al., 2012).

Action capabilities depend on body size, morphology, and dynamic capabilities, among other 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 movement of the perceive
is necessary for calibration of visual perception of affordance for a given behavior to (changed) action capabilities. However, such movement can be quite subtle and still be effective. For example, for behaviors that are primarily constrained by anthropometric properties, postural sway can be sufficient to calibrate visual perception of affordances to action capabilities (Mark, 1987; Mark et al., 1990; Stoffregen et al., 2009). However, for behaviors that are primarily constrained by dynamic capabilities (e.g., strength, flexibility, coordination), such subtle movement patterns may not be as effective. Under such circumstances, calibration of perception of affordances to (changed) action capabilities may require more overt exploratory or performatory behaviors such as explicitly performing the behavior or a related behavior (Stoffregen et al., 2009). For example, practice squeezing through narrow apertures was necessary for calibration of perception of affordances for this behavior, in part, because it attuned participants to dynamic capabilities that constrained their ability to perform this behavior (e.g., compressability, Franchak et al., 2010).

To the extent that affordances for a given behavior are constrained by dynamic (force production) capabilities in addition to static (geometric) properties, different experiences may be necessary and/or sufficient to bring about calibration of visual perception of that affordance. Calibration of perception of affordances that are primarily constrained by anthropometric properties may merely require practice perceiving, whereas calibration of perception of affordances that are additionally constrained by dynamic capabilities may require practice doing (Franchak et al., 2010).

4.5. Limitations of the current study

Our conclusions must be tempered to some degree by two methodological limitations. First, in the current experiment, the primary task of the participant was to report (rather than perform or act on) maximum stepping and leaping distance. In addition, to indicate perceived maximum stepping and leaping distance, participants adjusted the distance of a marker on a continuous support surface (i.e., no actual gap in the surface was present, cf. Burton, 1992; Jiang & Mark, 1994; Cole et al., 2013). Both of these features of the experimental design might have encouraged participants to adopt an analytic approach to what is typically a perception–action task. Heft (1993) showed that visual perception of whether an object was within reach was better calibrated to actual maximum reaching distance when the perception task was subsidiary to an action task (i.e., grasping a pen for use in a drawing task). Conversely, participants tended to overestimate their reaching ability when perception of maximum reaching distance was the primary task. In the current experiment, the overestimation observed in all three phases of the experiment (see Figs. 3 and 4) may have been due to adoption of an analytic approach to a perception–action task.

Second, in the current experiment, participants were asked to report the absolute maximum distance they could step or leap. During most everyday behaviors, people rarely perform any behavior at the absolute limits of their ability. Rather, they would likely switch to a different mode of performing the same behavior before the absolute limit on the behavior is reached. Mark et al. (1997) distinguished between an absolute critical boundary and a preferred critical boundary. An absolute critical boundary for a given behavior (e.g., horizontal reaching with the arm only) is the limit beyond which that behavior can no longer be performed successfully. A preferred critical boundary is the point at which a person would choose to transition from one behavioral mode to another (e.g., from horizontal reaching with the arm only to horizontal reaching with arm and torso) to accomplish the same behavioral goal. Both of these limitations of the current experiment might be overcome in a task that requires the participant to move from one location to another by means of traversing gaps of various sizes by either stepping or leaping. This may be another topic of future research.

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References


