Attention, Perception, & Psychophysics (2023) 85:2869–2878
https://doi.org/10.3758/s13414-023-02727-z

The psychophysics of affordance perception: Stevens' power law scaling of perceived maximum forward reachability with an object

Brandon J. Thomas[1] · **Sara Heiden**[1] · **Kristen Dyson**[1] · **Megan Bartz**[1] · **Jennah Curtin**[1] · **Vendela Zbotaniw**[1]

Accepted: 4 May 2023 / Published online: 24 May 2023

Abstract

The literatures on affordance perception and psychophysics are seminal in the basic study of perception and action. Nevertheless, the application of classic psychophysical methodologies/analysis to the study of affordance perception remains unexplored. In four experiments, we investigated the Stevens' power law scaling of affordance perception. Participants reported maximum forward reaching ability with a series of rods (both seated and standing) for themselves and another person (confederate). Participants also reported a property of the rod set that has been explored in previous psychophysical experiments and changes in equal measure with forward reach-with-ability (length). In all, we found that affordance perception reports ($\beta = .32$) were an underaccelerated function of actual changes in reaching ability compared with relatively less accelerated length reports ($\beta = .73$). Affordance perception scaled with stimulus magnitude more similarly to brightness perception than length perception. Furthermore, affordance perception reports scaled similarly regardless of the actor (self and other), task context (seated and standing), or idiosyncrasies of the measurement procedure (controlling for distance compression effects), while length perception reports were sensitive to location/distance compression effects. We offer empirical and theoretical considerations, along with pathways for future research.

Keywords Affordance perception · Ecological psychology · Psychophysics · Stevens' law · Perception · Power law

In Gibson's (1966a, b, 1979) ecological approach to perception and action, the organism and environment are treated as a unitary system or ecological niche. Gibson coined the term *affordance*, which is a complex/emergent variable within that system consisting of action capabilities of the organism and physical properties of the environment (for good reviews of the affordance literature, see Barsingerhorn et al., 2012; Wagman, 2019). For example, a riser is a step-on-able if a ratio is met between leg length and riser height (Warren, 1984). Organisms must detect these intrinsic properties to behave adaptively within the ecological niche. It is likewise necessary to perceive the affordances of other organisms for the purpose of adaptive social interaction and the existing body of evidence suggests humans are adept at doing so (Creem-Regehr et al., 2013; Marsh et al., 2009; Ramenzoni et al., 2008; Zhu & Bingham, 2010). Notwithstanding the extensive research on affordance perception over the last several decades, there remain open questions about the basic *psychophysics* of affordance perception for both the self and another person. We address some of these questions in four experiments using a classic psychophysical method and framework.

Psychophysics has a long and important history as the precursor to psychology as a discipline (Fechner 1860/1966; Stevens, 1957, 1960, 1975). The original charge of psychophysics was to determine the quantitative relationship between reality and sensation. Decades of research have produced a series of competing models, and while psychophysics has evolved into primarily a methodological and analytical framework in contemporary psychology, it still offers a useful and reliable quantitative approach for understanding perception. We adopted Stevens's (1975) classic framework to investigate the psychophysics of affordance

Statement of public significance This study demonstrates the utility of quantitative tools from traditional psychophysical techniques for researchers to understand how organisms perceive and behave in the environment. These efforts could have implications as far-reaching as the design of medical equipment or the construction of more realistic virtual environments.

✉ Brandon J. Thomas
thomasb@uww.edu

[1] Remembering, Acting, and Perceiving (RAP) Lab, Department of Psychology, University of Wisconsin–Whitewater, Whitewater, WI, USA

perception. Stevens posited that the psychophysical relation is best described as a power law function (see Eq. 1):

$$S = k\,R^{\beta}, \qquad (1)$$

where S is the detected sensation, k is the scaling constant, R is the stimulus, and β is slope, which is given by Eq. 2:

$$\beta = \frac{log\ s}{\log r}, \qquad (2)$$

where s is the sensation and r is the stimulus. The equation captures the acceleration in perceptual reports across the stimulus magnitude conditions. Thus, the slope captures acceleration such that $\beta = 1$ is nonaccelerated, $\beta < 1$ is underaccelerated and $\beta > 1$ is overaccelerated. In other words, β determines whether the rate of change in perceptual reports increase or decrease across stimulus magnitudes (perceptual/stimulus continua). Furthermore, Auerbach (1971) demonstrated that differences in β reflect differences in discriminability to changes in stimulus magnitude. Thus, there is a positive relationship between discriminability and β. Stevens found that different perceived and actual magnitudes of a stimulus produce different β values. Decades of research has demonstrated that β varies with different perceptual continua (i.e., physical properties; Stevens, 1957, 1960, 1975). For instance, perceived length ($\beta = 1.0$; Stevens & Galanter, 1957; Stevens & Guirao, 1963). is discriminated ideally, but perceived brightness produces an underaccelerated function ($\beta = .35$) (Stevens, 1953, 1975; Stevens & Stevens, 1963).

Psychophysical theories are conceptually divergent from ecological psychology as they emphasize the lawful relationship between sensory responses and physical stimuli as opposed to the lawful relationship between organism–environment and perception–action. In fact, Gibson (1966a, b) critically evaluated sensation and rejected it as the starting point of perception. Nonetheless, this is not an attempt to accommodate or critically evaluate the two theoretical approaches. It is instead an attempt to learn more about affordance perception via psychophysical methodology and analysis. Psychophysical methodology is framed as the study of sensation, but it does not normally involve studying the activity of sense receptors. Physical properties have been used as perceived stimuli much like contemporary perceptual experiments. Thus, as the methods of psychophysics continue to be useful, the analytic techniques can prove to be useful as well. We are unaware of any prior attempt to investigate the psychophysics of affordance perception using Stevens' power law function. The results of this study will inform the affordance literature about the *discriminability* of affordance perception. To address the gap between the affordance perception and psychophysics literatures, we estimated β for multiple affordance perception tasks. We also compared affordance reports of objects to visually perceived length reports, which have been investigated in past research and which was confounded with the affordance perception stimuli, making it an ideal control condition (Stevens & Galanter, 1957; Stevens & Guirao, 1963). By investigating the power law scaling between affordance perception and stimulus magnitude, we stand to learn more about (1) an unexplored quantitative description of affordance perception, (2) how affordance perception relates to other perceptual phenomena studied using power law functions, (3) whether the power law scaling of the perception of affordances vary for the self and another person or under different contextual, perspective, and biomechanical constraints, and (4) the theoretical implications of the discriminability of affordance perception.

The current study

In a series of experiments, we used Equation 1 to determine β for the affordances perception of seated and standing maximum forward reach with an object. We also determined β for the length reports of the same set of objects, which changes linearly with the actual reach-with-ability. We sought to (1) determine the power law scaling exponent for the affordance perception of maximum reach-with-ability for the self and another person and (2) compare the scaling exponent for affordance perception to the perception of a previously investigated and confoundingly manipulated, control property (length). Quantitative differences in the perception of affordances and the perception of relevant physical properties have been documented in a number of studies (Mark, 1987; Thomas & Riley, 2014, 2015; Thomas et al., 2016; Wagman et al., 2013, 2019b). We expected that we might find that affordance perception would scale differently with stimulus magnitude than length perception. The literature is mixed on the quantitative relationship between self versus other affordance perception, so this study will reveal insights about the relationship between individual and social affordances as well.

Experiment 1: Maximum seated reach-with-ability for the self and another person

Method

Participants Sixty-one undergraduates ($n = 30$ for the affordance conditions and $n = 31$ for the length condition) from University of Wisconsin–Whitewater participated for course credit. Written informed consent was obtained prior to data collection. One participant was removed from the reaching

Table 1 Metric properties of the rods used in Experiments 1–4

Length	Mass
8 cm	18 g
11 cm	27 g
14 cm	32 g
17 cm	44 g
20 cm	45 g
23 cm	51 g
26 cm	63 g
29 cm	66 g
32 cm	72 g
35 cm	80 g

The diameter of all rods was .22 cm

task data because a clerical error caused there to be a missing set of rod length trials. The sample consisted of 44 females and 17 males, and their average age was 19.6 yrs. Participants had an average height = 169.1 cm, weight = 69.9 kg, actual max reaching ability without a rod = 58.7 cm, arm length = 73.4 cm, and eye-height = 158.8 cm. We conducted an a priori power analysis using Soper's (2021) calculation tool, using data from a similar maximum reaching affordance study, which also compared affordance reports to stick length reports (Thomas & Riley, 2014). In their comparison between perceived reach-with-ability and length reports, they found an effect size of .88. For power of .80, we estimated the need for a minimum of 17 participants to detect an effect.

Design The study was originally a two-group, within-subjects design. Participants reported the maximum forward reach-ability with a series of rods for themselves on half the trials and for a confederate on the other half. We subsequently added the length report condition, in which a separate set of participants reported the length of the same series of rods.

Materials and apparatus The rod set utilized in all three experiments is detailed in Table 1. The rods were clear PVC pipes.

The report apparatus was a wooden rectangularly shaped table (250.2 cm × 64.8 cm × 71.1 cm). See Fig. 1. A pulley system was attached to the top of the right-hand side of the apparatus. The pulley had an arrow-shaped marker made of cardboard and duct tape that participants adjusted to make their reports. A tape measure was affixed to the side of the apparatus for the experimenter to record reports. The tape measure was covered in tape and out of view of the participant. The apparatus' surface is lightly colored wood. The center of the foldable apparatus was covered in manila folders to create a more uniform surface.

Participants sat on an office chair that was a constant distance from the report apparatus (d = 63.8 cm from the back of the chair to the edge of the report apparatus). The distance was specified by a piece of tape on the floor where participants were asked to adjust the legs of the chair so that they were lined up with it. The confederate was seated to the left of the participant on an identical office chair while

Fig. 1 The report apparatus and laboratory setup for Experiment 1. The participant (left) is making an affordance report by adjusting the pulley. The confederate (right) is seated next to the participant throughout the report phase. No confederate was present for the length report condition. The rod (not pictured) was displayed off screen to the right of participants one at a time

lined up with an equidistant floor marker in the affordance conditions. The confederate remained seated and relatively motionless until after all reports were given.

Procedure Upon entering the laboratory, informed consent was obtained from participants by the experimenter. Participants were asked to sit on an office chair in front of the report apparatus (see Fig. 1). Once seated, participants lined the front of the chair up with a piece of tape on the floor. A confederate was seated in an office chair to the left of the participant. The confederate made minimal movements and did not stand in the presence of the participants until after all perceptual reports were recorded. There were three confederates (standing height: M = 168.2, arm length: M = 71.5, actual reach without a rod: M = 71.3) who alternated across participants. In the length condition (which we ran between-subjects after the affordance conditions), there was no confederate present.

Participants were then given the instructions. The participants in the two affordance conditions were told that they would be shown a series of rods and asked to report how far they (the self condition) or the confederate (the other condition) could reach with the displayed rod across the report apparatus as far they (or the confederate) could without lifting off the chair. They were told to use the pulley system to adjust the marker on the surface of the report apparatus to the distance away that they could just barely reach. They received similar instructions in the length condition, except they were told to adjust the marker to the distance away that matched the length of the displayed rod. Half of reports were made with the marker either starting at the end of the apparatus and moving toward the participant (incoming) or starting near the participant and moving away from the participant (outgoing). This manipulation was added to control for hysteresis effects that have been shown to bias affordance reports (Lopresti-Goodman et al., 2013). Participants in the affordance conditions made two reports for each rod length (10) × self/other affordance (2) × incoming/outgoing trial (2) for a total of 80 trials, randomized within and across participants. The length condition had the same experimental design aside from self/other reports, so they completed a total of 40 trials.

Once all of the reports were obtained, participants' actual reaching ability (without the rods), standing height, eye-height, and arm length were measured. Finally, participants were debriefed about the goals of the study. The study took approximately 45 minutes to complete.

Results

We calculated β for the relationship between perceptual reports (cm) and the actual length of the rods (cm) for each participant individually as specified in Eq. 1. The descriptive statistics are given in Table 2.

Table 2 Mean perceptual reports (cm) for each reporting condition in Experiment 1

Rod length	Length report	Self report	Other report
8	12.5 (12.6)	59.9 (21.6)	60.1 (22.4)
11	15.7 (4.8)	67.1 (22.4)	65.5 (22.4)
14	18.0 (5.0)	69.3 (23.5)	66.4 (21.4)
17	24.4 (6.5)	74.4 (26.9)	74.0 (24.3)
20	24.3 (7.0)	74.1 (22.5)	74.7 (25.6)
23	27.3 (8.3)	78.6 (24.1)	78.6 (22.5)
26	33.5 (8.2)	96.5 (82.3)	87.3 (23.6)
29	35.0 (9.4)	86.8 (25.6)	90.8 (25.0)
32	39.0 (8.2)	93.9 (26.2)	91.6 (20.0)
35	44.1 (11.5)	98.5 (26.8)	97.6 (25.7)

Self and other reports are from the same participants and length reports are from separate participants. Standard deviations are in parentheses

We used the mean for each condition to run the rest of the analysis. We compared β of the affordance conditions and the length condition in separate t tests because the variable is not fully crossed. We conducted a paired-samples t test on the mean self and other report βs. The self report β (M = .37) did not significantly differ from the other report β (M = .38), $t(29) = .66$, $p = .518$, $d = .07$. We compared the mean β for each affordance condition with the length condition in separate independent-samples t tests. The length report β (M = .89) was significantly greater than the self report β, $t(59) = 10.51$, $p < .001$, $d = 2.67$. The length report β was also significantly greater than the other report β, $t(59) = 10.03$, $p < .001$, $d = 2.56$ (Table 3).

Experiment 2: Maximum standing reach-with-ability

We found that the Stevens' law β was significantly different for length perception and reach-with-ability for the self and another person while seated. We sought to determine whether this same relationship holds for standing forward reach-with-ability. This task is different in multiple ways. Standing reach involves more complex and difficult postural systems than seated reach so it has implications for postural stability (Butler et al., 2011; Duncan et al., 1990; Gabbard et al., 1999, 2007). Standing reach is also more dangerous because falling is possible and requires a higher, more dynamic, and angularly steeper viewpoint.

Method

Participants Thirty undergraduates from University of Wisconsin–Whitewater participated for course credit. Written informed consent was obtained prior to data collection. The sample

Table 3 The average β for each condition of each experiment

Experiment	Task	Property	Avg β
1	Seated	Self affordance	.37 (.04)
1	Seated	Other affordance	.38 (.04)
1	Seated	Length	.89 (.03)
2	Standing	Self affordance	.26 (.02)
2	Standing	Other affordance	.27 (.03)
2	Standing	Length	.76 (.02)
3	Seated	Length	.24 (.02)
4	Seated	Self affordance	.26 (.03)
4	Seated	Length	.79 (.04)

*SEM*s are in parentheses

consisted of 22 females and eight males, and their average age was 19.8 yrs. Participants had an average height = 163.5 cm, weight = 72.3 kg, actual max reaching ability without a rod = 88.1 cm, arm length = 75.4 cm, and eye-height = 157.6 cm.

Design The study had a single within-subjects variable of report (self, other, length), which included reports about how far forward they or another person could reach while holding the visually presented object. The reports were either about how far the participant or a confederate could reach with a rod or the length of the rod. The study took about 30 mins.

Materials and apparatus The rod set was the same as Experiment 1 (see Table 1). The confederates were also the same individuals as those in Experiment 1. However, the report apparatus was replaced by the experimental setup displayed in Fig. 2. We used a report procedure that is often used to evaluate the postural stability risks of older adults (Duncan et al., 1990). Participants reported maximum forward reach with an object for themselves and a confederate. They also reported the length of each object. They did so by using a laser pointer to indicate how far they could reach along the wall adjacent to them (or how long the rod was in the length condition). A tape measure was fixed to the wall (203.2 cm off the floor) and covered in Post-It© notes so that participants could not see their reports. The confederates also served as the experimenter. They stood next to the participant in a designated area identified by a piece of tape on the floor (see Fig. 2).

Procedure Upon entering the laboratory, participants were asked to sign a consent form. They were then given the instructions of the study. They were told that they would report the length of the rods along with the distances they or a confederate could reach with each rod if they leaned forward with their outstretched arm as far as they could without falling over. They also reported the length of the rods. There were 10 rods and three report conditions that were randomized across and within participants, totaling 30 trials. After all trials were completed, participants anthropometric properties were measured and they were debriefed as in Experiment 1.

Results

We calculated β separately for each participant and averaged them within each report condition (self, other, and length) as

Fig. 2 Participants (right) reported how far forward they or a confederate/experimenter (left) could reach with a rod, shown visibly, without falling over, along with the length of the rod, by pointing a laser pointer at the wall-affixed report apparatus. The rod (not pictured) was displayed just to the right of the experimenter

Table 4 Mean perceptual reports (cm) for each reporting condition (length, self, other) for Experiment 2

Rod length	Length report	Self report	Other report
8	16.1 (3.4)	81.0 (21.2)	79.9 (19.5)
11	21.5 (7.3)	83.5 (17.1)	82.6 (16.8)
14	24.7 (5.9)	88.8 (18.0)	87.6 (16.9)
17	33.0 (8.9)	94.1 (15.1)	90.2 (17.0)
20	33.3 (7.4)	91.5 (19.0)	91.3 (19.0)
23	36.4 (7.4)	101.3 (17.7)	95.9 (15.9)
26	41.8 (9.2)	106.5 (13.9)	103.4 (18.2)
29	43.1 (7.6)	107.5 (16.1)	106.6 (17.5)
32	45.8 (9.4)	111.9 (16.6)	108.0 (19.6)
35	49.7 (12.0)	117.5 (15.4)	116.1 (19.8)

Standard deviations are in parentheses

in Experiment 1 (see Table 4 for descriptive statistics). Since the conditions were exclusively within-subjects, we conducted a one-way, within-subjects analysis of variance (ANOVA) on the mean β for each report condition. The effect was significant, $F(2, 58) = 140.68$, $p < .001$, $\eta_p^2 = .83$. We conducted a series of post hoc, Bonferroni-corrected t tests and found that the length report β ($M = .76$) was significantly greater than both the self report β ($M = .27$) and other report β ($M = .26$), $p < .001$. The self and other report β did not significantly differ, $p = 1.00$ (see Table 3).

Experiment 3: Location effect control study

Stevens' law has been subject to several decades of empirical scrutiny, and confounding contextual effects are common issues with the approach (Bernasconi & Seri, 2016; Molski, 2011). Location effects in particular, wherein measurements of perception and sensation that are influenced by their distance away from the center of the measurement scale, are of particular concern (Engen & Levy, 1955; Fagot & Pokorny, 1989; Kowal, 1993; Pradham & Hoffman, 1963). It is possible that this measurement confound produced a location effect, especially since distance compression would be greater in the affordance conditions. Significant distance compression could bias responses towards lower values of β, as was observed in Experiments 1 and 2.

To control for distance compression and location effects, we conducted a follow-up study that designated the mean minimum reach-ability *without* a rod from Experiment 1 (d = 64.5 cm) as the starting point for length reports. Thus, the reports were placed within the same range of the reach-with-ability reports. We expected that this tweak in the design of the study might reveal any distance compression effects inherently produced by our methodology by potentially decreasing length report β in a manner similar to affordance reports.

Method

Participants Fifteen undergraduates from University of Wisconsin–Whitewater participated for course credit. Written informed consent was obtained prior to data collection. The sample consisted of eight females and seven males, and their average age was 19.5 yrs. Participants had an average height = 174.1 cm, weight = 79.0 kg, actual max reaching ability without a rod = 87.1 cm, arm length = 76.5 cm, and eye-height = 163.5 cm.

Design The study had a single length report condition. Participants estimated how long the rod was as in Experiments 1 and 2. They did not report any affordances. The study took about 30 mins.

Materials and apparatus The rod set was the same as Experiments 1 and 2 (see Table 1). The report apparatus was also the same as Experiment 1, except length reports were given starting at the average minimum reaching reports from Experiment 1 (64.5 cm away from the near end of the table) to put the reaching and length reports in the same location on the report apparatus.

Procedure The procedure was identical to Experiment 1 except for the length reports which were given at a further starting point.

Results

We calculated β for the length reports x actual length for each participant (n = 15) and averaged across participants (M = .24). See Table 5 for descriptives. To evaluate our hypothesis, we compared β for length reports in Experiment 3 to self and other affordance reports in Experiment 1 in separate planned t tests. The mean β for self reports (M = .36) in Experiment 1 was significantly greater than length reports in Experiment 3, $t(43) = 2.12$, $p = .033$, $d = .79$. Furthermore, the other reports (M = .38) were significantly greater than length reports in Experiment 3, $t(43) = 2.41$, $p = .020$, $d = .86$ (see Table 3).

Experiment 4: Perspective bias control study

Experiment 3 demonstrated a sizable location effect on β for length reports that was likely the result of perceptual distance compression. The average β for the length and affordance reports actually reversed in magnitude. These results demonstrate that the β observed for length reports in the prior experiments can be significantly truncated by distance compression. These findings beg the question: Can affordance perception reports be inversely unbiased on the

Table 5 Mean perceptual reports (cm) for each reporting condition

Rod length	Length report (Exp 3)	Length report (Exp 4)	Self report (Exp 4)
8	72.6 (10.0)	13.1 (3.7)	68.6 (19.3)
11	75.9 (9.5)	17.2 (3.8)	72.6 (18.5)
14	78.9 (9.5)	19.2 (4.0)	75.0 (17.7)
17	82.9 (8.0)	24.2 (3.8)	80.7 (19.5)
20	85.8 (10.8)	24.5 (3.8)	81.1 (18.8)
23	87.1 (11.3)	28.7 (4.7)	86.0 (19.7)
26	93.2 (9.9)	33.7 (11.2)	88.6 (18.4)
29	96.4 (9.8)	34.0 (6.0)	91.4 (19.1)
32	96.6 (8.6)	36.6 (4.7)	97.2 (19.0)
35	101.1 (8.7)	42.3 (7.6)	98.09 (22.2)

Length reports are from Experiments 3 and 4. Standard deviations are in parentheses

measurement scale by controlling for distance compression? If so, we expect that controlling for distance compression effects will similarly lift β closer to 1 for both the affordance and length report conditions. We designed Experiment 4 to test this hypothesis.

Method

The method was similar to Experiment 3. Using the seated report apparatus, participants reported forward reach-with-ability for the self and rod length in separate counterbalanced blocks in random order across actual rod lengths and between participants, resulting in two report conditions: affordance or length. Additionally, participants made affordance reports as if they were seated, but they were asked to stand and take a top-down view of the report apparatus on both length and affordance reports. Thus, distance compression was controlled across report conditions because the participants were able to inspect the distance of the report apparatus from an angle that strictly limited distance compression effects. Thus, there were two reports per 10 rods × 2 report condition blocks × 2 marker movement direction (incoming/outgoing), resulting in 40 total trials. The study took about 45 mins.

Results

We calculated β for the length reports x actual length for each participant ($n = 21$) and averaged across participants for each condition. The descriptive statistics are in Table 5. We compared the length report β ($M = .79$) with the self report β ($M = .26$) in a paired-samples t test. The length report β were significantly greater than the self reports β, $t(20) = 12.94$, $p < .001$, $d = 2.78$. β for length reports returned to a value similar to Experiment 1, while affordance report β remained virtually unchanged, suggesting that distance compression selectively affects the psychophysical scaling of length and not the perception of forward reach-with-ability (seated or standing). See Table 3.

Discussion

We sought to explore affordance perception by adopting Stevens' power law framework in an affordance perception task. With regard to our specific research questions, we found (1) that affordance perception can be captured using Stevens' power law framework, (2) that the affordance tasks used produce relatively small βs across experiments ($M = .31$), particularly when affordance reports are compared to the well-explored β of length perception ($M = .73$), even though the change in magnitude of the two properties are confounded with each other, (3) the β for affordance perception was reliable regardless of the actor (self vs. other) reported on, biomechanical constraints, or the perspective viewpoint as the self ($M = .30$) and other ($M = .32$) report βs didn't differ across experiments. We will explore some implications for the affordance perception literature in what follows.

With respect to the psychophysical properties of affordance perception, we found that Steven's law usefully captures the scaling of both individual and social affordances. By adding the length control condition, we were able to place the β for affordance perception within the framework of previously investigated psychophysical continua. Stevens's (1975) reported $\beta = 1$ for length perception. We obtained a decidedly smaller value across experiments $\beta = .73$ for length perception.[1] It is unclear why we found this lower value for β. It is possible that this was because we had participants perceive the length of actual objects rather than two-dimensional line segments (Stevens & Guirao, 1963). Also, the orientation of the to-be-perceived rods were horizontal and participants

[1] We excluded the length reports from Experiment 3, since those were biased by the range effect described earlier.

reported length along the sagittal axis. This could have led to some noise that lowered the average length β.

Nonetheless, we consistently obtained values of β for length that were greater than affordance perception. Interestingly, the β we consistently obtained for affordance perception was low with respect to other documented length values (β = .31 across all experiments). Thus, even though length perception is inherent in the perception of reach-with-ability, it scales differently with changes in stimulus magnitude. Affordance perception is more akin to brightness perception (Stevens, 1953, 1975; Stevens & Stevens, 1963). We did not find any differences in the perceptual scaling between social affordances (M = .34) and individual affordances (M = .31). Still more, β was greater for seated (M = .36) than standing (M = .26) affordance perception. It is unclear whether the differences and similarities across these affordance perception variables are significant theoretically as β can vary across tasks for the same property. We offer a potential theoretical account below. In any case, this study serves as a novel investigation of affordance perception with a psychophysical analytic framework. It will be up to future studies to explore the psychophysics of different affordances and affordance tasks.

We also found across Experiments 3 and 4 that length perception was sensitive to location effects, but affordance perception was not. We found that attenuating distance compression effects boosted β for length perception but affordance perception β was robust against these effects. These last two experiments were necessary to control for methodological confounds, but they also may offer theoretical insights. We found that forward-reach-with-ability affordance perception is underaccelerated. Additionally, we found that this pattern is reliable across different measurement procedures, unlike length perception. The psychophysics of affordance perception are both underaccelerated *and* reliable.

To this point, we have focused on the quantitative implications of our findings. There are implications for affordance perception theory as well. We did not adopt Stevens' theoretical views on sensation and reality. We instead used the power law analysis and methodological strategy to learn novel things about affordance perception. In Gibson's ecological approach to perception-action, the organism-environment system is rich with energetic media that the environment invariantly structures (Gibson, 1979). Gibson redefined the term *information* to account for these structured energy arrays that specify all elements of an ecological niche. Thus, perception is accomplished by producing and detecting information through action. For example, research has demonstrated that a variety of object and affordance properties are specified by invariant rotational inertia information which are detected by multiple modalities (Shockley et al., 2004; Streit et al., 2007a; Turvey et al., 1999).

The information that specifies visually perceived seated and standing reach have been studied for decades (Bingham & Stassen, 1994; Carello et al., 1989; Watt & Bradshaw, 2003). Recently, Mantel et al. (2015) found that egocentric distance is specified and perceived by dynamically generating haptic/inertial-visual information. Participants made reach-ability reports in this study. The difference in scaling we found between length perception and reach-with-ability perception suggests that the information for length perception and reach-with-ability are different likely not equivalent. We found that perceived forward reach-with-ability scaled underaccelerated with the change in actual reach-with-ability. There are a number of theoretical explanations that could account for these findings. Because the information for these particular affordances and lengths are not fully understood, the information that participants detected to perceive these affordances specify something other than the change in stimulus length manipulated. It is also possible that participants are not fully calibrated to the affordances in our tasks, which can sometimes require feedback (Mark, 1987; Thomas et al., 2016; Withagen & Michaels, 2007).

On the other hand, affordances might be perceived more dynamically, such that the detection of affordances becomes more granular as an organism approaches action completion. In other words, it is possible that there is a negative spatial-temporal relationship between the discriminability of the affordances and the end-point of the task. Affordances are often nested within each other, so it's possible that end-point affordances become more discriminable as participants perform the sub affordances to reach that end point. It would be useful to tested whether manipulating spatial-temporally nested affordances produces difference βs not unlike others have in exploring nested affordances (Wagman et al., 2016, 2019a).

Similarly, it's possible that neither of our reaching tasks required a precise enough movement to require ideal discrimination. Forward reach with an object is a relatively imprecise action that doesn't require much motor dexterity. Perhaps, we will find a β nearer to 1 with a task that requires a more precise movement like hammering (Wagman & Carello, 2003; Wagman & Shockley, 2011). Future research will be necessary to sort out these explanations.

We also need to address the lack of a difference β across the self and other affordance conditions. Perhaps the findings have implications on the nature of social affordance perception (see Wagman et al., 2019a, b). These results might be consistent with theories that posit a ubiquitous mechanism for the perception of affordances for the self and other people (see Wagman et al., 2019a, b). On the other hand, the scaling we observed might generalize across affordance domains, so more empirical work is required. A similar discussion is warranted for the reliable lack of difference in β between self and other affordances.

Similarly, it is unclear how general our findings are. More research is needed on other affordance tasks (step-on-ability, pass-through-ability, etc.) and with other methodologies (e.g., fractionation, match-to-standard) to explore whether the β we observed generalizes to reaching affordances or affordances writ large. We did find that location effects did not affect β for affordance perception. Perhaps, perspective methodological invariance is a hallmark characteristic of the psychophysics of affordance perception. Certainly, this would be an adaptive feature for the dynamic control of actions. Future research will be needed to understand more about this topic.

There are also limitations of the study that should be addressed in future research. Reporting procedures for Experiments 1 and 2 were different in significant ways (laser pointer vs. pulley system), which could have contributed to the difference in average β in these tasks. Though, average variability was comparable across tasks (see Tables 2 and 4). Also, the mean reduction in β for the standing task might be attributable to the increased postural complexity. The variability in the standing movement itself might have been why discriminability was lower. Disentangling these possibilities is important for future research by using more similar reporting measures across tasks. Moreover, participants made fewer reports than in past psychophysics experiments. There were four reports for each condition (one outgoing and one incoming) in Experiments 1, 3, and 4. In Experiment 2, there was only a singly trial per rod × reporting condition. We opted for a shorter length for the experiment since adding more trials would have increased the total number of trials by a factor of 4. It would be useful for future research to increase the number of trials. Finally, we did not record actual reach-with-ability for all the rods separately. We only recorded it for reach-ability without the rods. As a result, we were not able to properly calculate perceived/actual ratios, perceptual error, or other accuracy measures. It would useful for future research to more measure all the actions performed in a task so that these measures of perceptual scaling can be compared to the power law scaling calculation.

Conclusion

We used Stevens' power law function to explore affordance perception for varying actors (self or other), tasks (seated or standing), and measurement procedures. We found that the Stevens' Law β for affordance perception was underaccelerated/less discriminative but more reliable than perceived length regardless of the aforementioned manipulations, even though actual length and maximum forward reaching ability with the objects change in equal measure. Our work has implications for basic science on affordance perception.

Open practices statement The data and materials for all experiments are available (https://osf.io/r2qsd/).

References

Auerbach, C. (1971). Interdependence of Stevens' exponents and discriminability measures. *Psychological Review, 78*(6), 556.

Barsingerhorn, A. D., Frank, T. J. M., Zaal, Smith, J., & Pepping, G. (2012). On possibilities for action: The past, present, and future of affordance research. *The Journal of the Philosophical-Interdisciplinary Vanguard, 3*, 54–69.

Bernasconi, M., & Seri, R. (2016). What are we estimating when we fit Stevens' power law? *Journal of Mathematical Psychology, 75*, 137–149.

Bingham, G. P., & Stassen, M. G. (1994). Monocular egocentric distance information generated by head movement. *Ecological Psychology, 6*(3), 219–238.

Butler, A. A., Lord, S. R., & Fitzpatrick, R. C. (2011). Reach distance but not judgment error is associated with falls in older people. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences, 66*(8), 896–903.

Carello, C., Grosofsky, A., Reichel, F. D., Solomon, H. Y., & Turvey, M. T. (1989). Visually perceiving what is reachable. *Ecological Psychology, 1*(1), 27–54.

Creem-Regehr, S. H., Gagnon, K. T., Geuss, M. N., & Stefanucci, J. K. (2013). Relating spatial perspective taking to the perception of other's affordances: Providing a foundation for predicting the future behavior of others. *Frontiers in Human Neuroscience*, *7,* Article 596. https://doi.org/10.3389/fnhum.2013.00596

Duncan, P. W., Weiner, D. K., Chandler, J., & Studenski, S. (1990). Functional reach: A new clinical measure of balance. *Journal of gerontology, 45*(6), M192–M197.

Engen, T., & Levy, N. (1955). The influence of standards on psychophysical judgments. *Perceptual and Motor Skills, 5*(3), 193–197.

Fagot, R. F., & Pokorny, R. (1989). Bias effects on magnitude and ratio estimation power function exponents. *Perception & Psychophysics, 45*(3), 221–230.

Fechner, G. (1966). *Elements of psychophysics (Vol. 1).* Holt, Rinehart and Winston. (Original work published 1860)

Gabbard, C., Robinovitch, S. N., & Cronin, T. (1999). Perception of postural limits in elderly nursing home and day care participants. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences, 54*(3), B124–B130.

Gabbard, C., Cordova, A., & Lee, S. (2007). Examining the effects of postural constraints on estimating reach. *Journal of Motor Behavior, 39*(4), 242–246.

Gibson, J. J. (1966a). The problem of temporal order in stimulation and perception. *The Journal of Psychology, 62*, 141–149.

Gibson, J. J. (1966b). *The senses considered as perceptual systems*. Houghton Mifflin.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Houghton Mifflin.

Kowal, K. H. (1993). The range effect as a function of stimulus set, presence of a standard, and modulus. *Perception & Psychophysics, 54*(4), 555–561.

Lopresti-Goodman, S. M., Turvey, M. T., & Frank, T. D. (2013). Negative hysteresis in the behavioral dynamics of the affordance "graspable." *Attention, Perception, & Psychophysics, 75*, 1075–1091.

Mantel, B., Stoffregen, T. A., Campbell, A., & Bardy, B. G. (2015). Exploratory movement generates higher-order information that is sufficient for accurate perception of scaled egocentric distance. *PLOS ONE*, *10*(4), Article e0120025.

Mark, L. S. (1987). Eyeheight-scaled information about affordances: A study of sitting and stair climbing. *Journal of Experimental Psychology: Human Perception and Performance, 13*(3), 361–370.

Marsh, K. L., Johnston, L., Richardson, M. J., & Schmidt, R. C. (2009). Toward a radically embodied, embedded social psychology. *European Journal of Social Psychology, 39*(7), 1217–1225.

Molski, M. (2011). Extended Stevens' power law. *Physiology & Behavior, 104*(5), 1031–1036.

Pradham, P. L., & Hoffman, P. J. (1963). Effect of spacing and range of stimuli on magnitude estimation judgements. *Journal of Experimental Psychology, 66*(6), 533–541.

Ramenzoni, V. C., Riley, M. A., Shockley, K., & Davis, T. (2008). An information-based approach to action understanding. *Cognition, 106*(2), 1059–1070.

Soper, D. S. (2021). *A-priori sample size calculator for student* t*-tests* [Computer software]. Available from https://www.danielsoper.com/statcalc

Shockley, K., Carello, C., & Turvey, M. T. (2004). Metamers in the haptic perception of heaviness and moveableness. *Perception & Psychophysics, 66*(5), 731–742. https://doi.org/10.3758/bf03194968

Stevens, S. S. (1953). On the brightness of lights and the loudness of sounds. *Science, 118*, 576–579.

Stevens, S. S. (1957). On the psychophysical law. *Psychological Review, 64*(3), 153–181.

Stevens, S. S. (1960). The psychophysics of sensory function. *American Scientist, 48*(2), 226–253.

Stevens, S. S. (1975). *Psychophysics: Introduction to its perceptual, neural, and social prospects*. Wiley.

Stevens, S. S., & Galanter, E. H. (1957). Ratio scales and category scales for a dozen perceptual continua. *Journal of Experimental Psychology, 54*(6), 377–411.

Stevens, S. S., & Guirao, M. (1963). Subjective scaling of length and area and the matching of length to loudness and brightness. *Journal of Experimental Psychology, 66*(2), 177–186.

Stevens, J. C., & Stevens, S. S. (1963). Brightness function: Effects of adaptation. *JOSA, 53*(3), 375–385.

Streit, M., Shockley, K., Morris, A. W., & Riley, M. A. (2007a). Rotational kinematics influence multimodal perception of heaviness. *Psychonomic Bulletin & Review, 14*(2), 363–367. https://doi.org/10.3758/BF03194078

Streit, M., Shockley, K., & Riley, M. A. (2007b). Rotational inertia and multimodal heaviness perception. *Psychonomic Bulletin & Review, 14*(5), 1001–1006.

Thomas, B. J., & Riley, M. A. (2014). Remembered affordances reflect the fundamentally action-relevant, context-specific nature of visual perception. *Journal of Experimental Psychology: Human Perception and Performance, 40*, 2361–2371.

Thomas, B. J., & Riley, M. A. (2015). The selection and usage of information for perceiving and remembering intended and unintended object properties. *Journal of Experimental Psychology: Human Perception and Performance, 41*, 807–815.

Thomas, B. J., Wagman, J. B., Hawkins, M. M., Havens, M., & Riley, M. A. (2016). The independent perceptual calibration of action-neutral and -referential environmental properties. *Perception, 46*(5), 586–604.

Turvey, M. T., Shockley, K., & Carello, C. (1999). Affordance, proper function, and the physical basis of perceived heaviness. *Cognition, 73*(2), B17–B26.

Wagman, J. B. (2019). A guided tour of Gibson's theory of affordances. In J. B. Wagman & J. J. C. Blau (Eds.), *Perception as information detection: Reflections on Gibson's Ecological Approach to perception* (pp. 233–247). Routledge.

Wagman, J. B., & Carello, C. (2003). Haptically creating affordances: The user-tool interface. *Journal of Experimental Psychology: Applied, 9*(3), 175–187.

Wagman, J. B., & Shockley, K. (2011). Metamers for hammer-with-ability are not metamers for poke-with-ability. *Ecological Psychology, 23*(2), 76–92.

Wagman, J. B., Thomas, B. J., McBride, D. M., & Day, B. M. (2013). Perception of maximum reaching height when the means of reaching are no longer in view. *Ecological Psychology, 25*, 63–80.

Wagman, J. B., Caputo, S. E., & Stoffregen, T. A. (2016). Hierarchical nesting of affordances in a tool use task. *Journal of Experimental Psychology: Human Perception and Performance, 42*(10), 1627–1642.

Wagman, J. B., Cialdella, V. T., & Stoffregen, T. A. (2019a). Higher order affordances for reaching: Perception and performance. *Quarterly Journal of Experimental Psychology, 72*(5), 1200–1211.

Wagman, J. B., Thomas, B. J., & McBride, D. M. (2019b). Perceiving and remembering affordances for others are continuous processes. *Experimental Psychology, 65*(6), 385–392.

Warren, W. H. (1984). Perceiving affordances: Visual guidance of stair-climbing. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 683–703.

Watt, S. J., & Bradshaw, M. F. (2003). The visual control of reaching and grasping: Binocular disparity and motion parallax. *Journal of Experimental Psychology: Human Perception & Performance, 29*(2), 404–415.

Withagen, R., & Michaels, C. F. (2007). Transfer of calibration between length and sweet-spot perception by dynamic touch. *Ecological Psychology, 19*(1), 1–19.

Zhu, Q., & Bingham, G. P. (2010). Learning to perceive the affordance for long-distance throwing: Smart mechanism or function learning? *Journal of Experimental Psychology: Human Perception and Performance, 36*(4), 862–875.