Selection between differently scaled actions

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Introduction

As the environment contains innumerable affordances, organisms must act upon them selectively. Action selection is the problem of affordance realization (Davis, 2012).

According to the π-number approach to affordance perception, the perceivable distinction between possible and impossible actions is delineated by a dimensionless ratio of environmental dimensions to organism dimensions (Warren, 1984).

Perceptual scaling need not be by body dimensions; that is merely a convenient metric for the scientist. Scaling by action capability is a promising approach (Oudejeans et al., 1996; Fajen, 2005).

Scaling is relevant to not only affordance perception but also affordance realization. Transitions between two actions occur at body-scaled critical points (Warren & Whang, 1987; Lopresti-Goodman et al., 2011).

In this study, participants selected between stepping over and walking around an obstacle of varying height and width. These actions implicate different dimensions and action capabilities, unlike in previous studies.

Methods

Twenty University of Connecticut undergraduates participated in this experiment (10 males; ages 18-20).

Participants walked from a start location to an end location, each a distance $d_{obs.}$ = 5 ft. from an obstacle between them (pictured in Fig. 1).

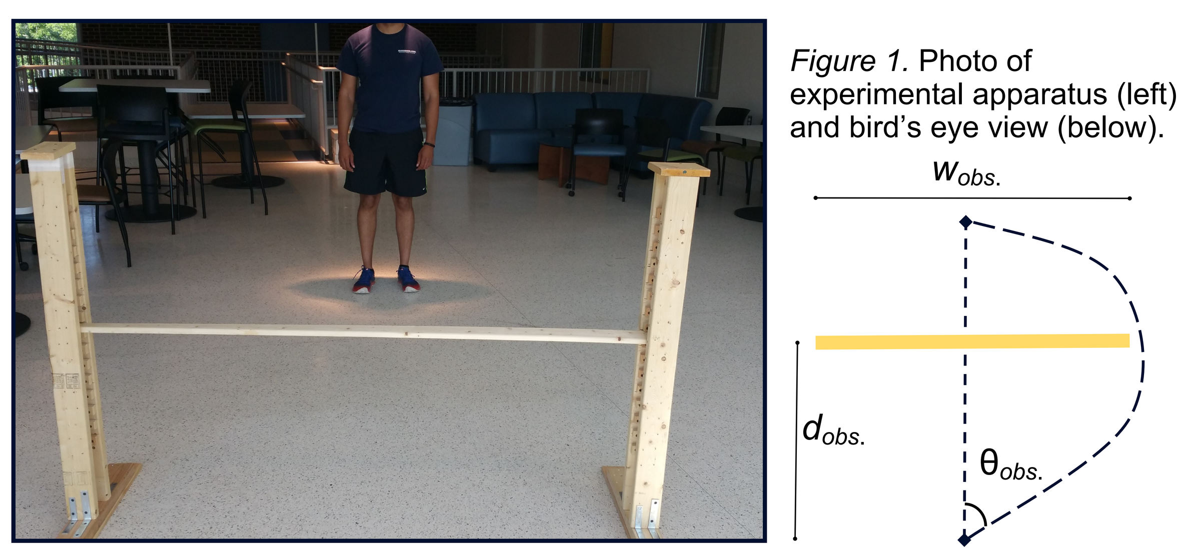

Figure 1. Photo of experimental apparatus (left), and bird's eye view (below).

We instructed participants to either step over or walk around the obstacle as was “comfortable, natural, or automatic.” Their choice was recorded on both the outbound trip and the return to the start position.

We began each session by determining the maximum obstacle height the participant could step over comfortably ($h_{max.}$). This was used as a baseline for the obstacle heights ($h_{obs.}$).

Additionally, we measured participants' knee heights and hip heights.

Design

Six obstacle widths ($w_{obs.}$)	Seven obstacle heights ($h_{obs.} - h_{max.}$)
4.5, 6, 7.5, 9, 10.5, 12 ft.	+2, -2, -4, -6, -8, -10, -14 in. (relative to affordance boundary)

All conditions except +2 in. height were presented twice, fully randomized, for a total of 78 trials per participant.

Results

The proportion of trials in each condition exhibiting each action were calculated. These are shown in Fig. 2.

Participants appeared to trade off obstacle height and obstacle width. As obstacle width increased, participants were more likely to step over the obstacle. As obstacle height increased, participants were more likely to walk around the obstacle.

We ran a series of mixed-effect logistic regressions on the trial outcomes. The model fit was significantly improved when adding fixed and random effects of obstacle width, relative obstacle height, and experiment phase (outbound vs. return), $p < .001$.

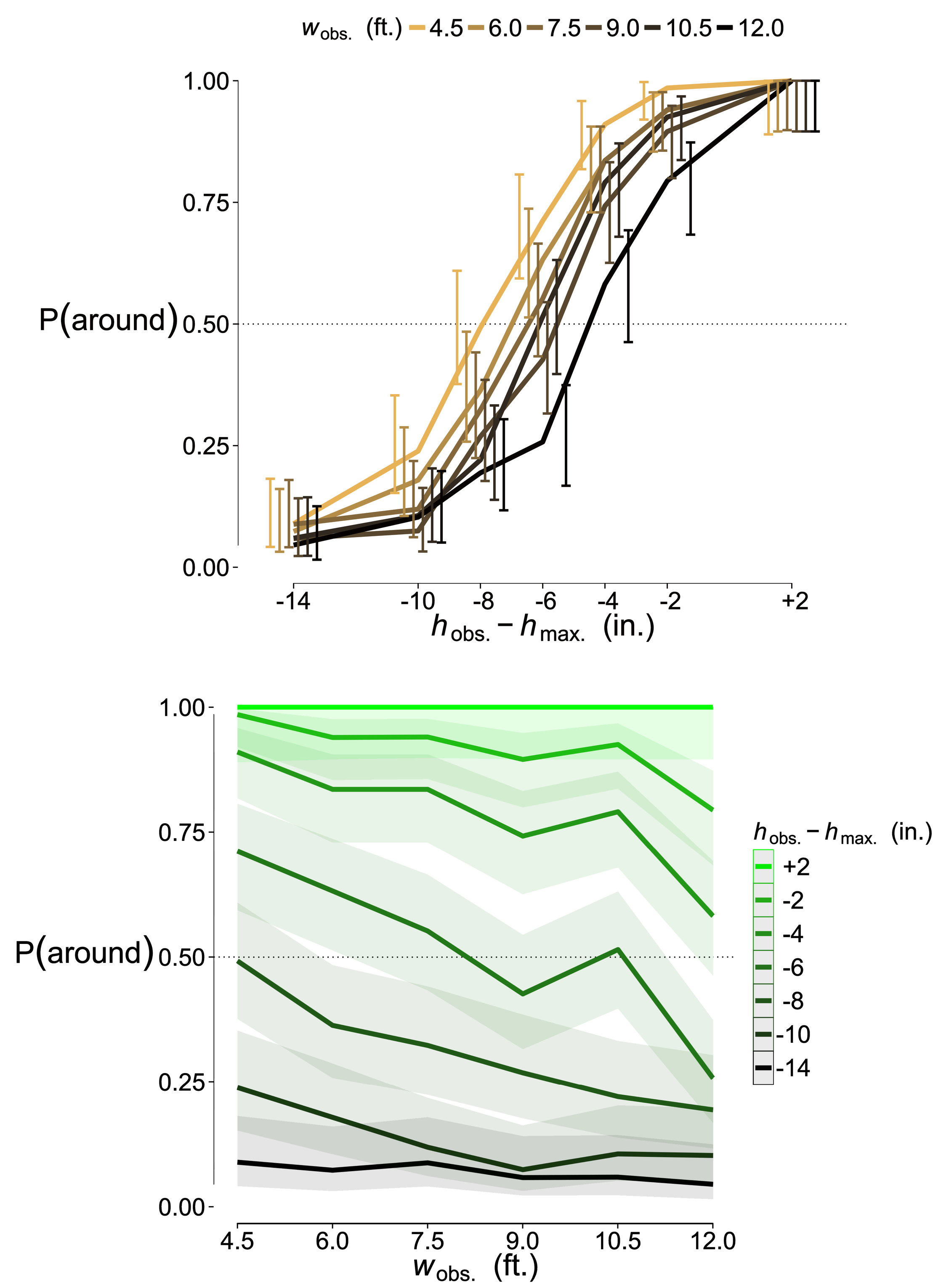

Figure 2. The proportion of trials in each condition in which the participant walked around the obstacle rather than stepping over it. The same data points are shown grouped by width condition (top) and relative-height condition (bottom). Error bars and ribbons are 95% confidence intervals estimated using the Wilson method.

Critical-height analysis

Using logistic regressions, we estimated a critical obstacle height for each participant and each obstacle width. The critical height was defined as the height at which the regression predicted that either action was equally likely. Figure 3 shows the mean critical heights for each obstacle width, scaled by measured affordance boundary.

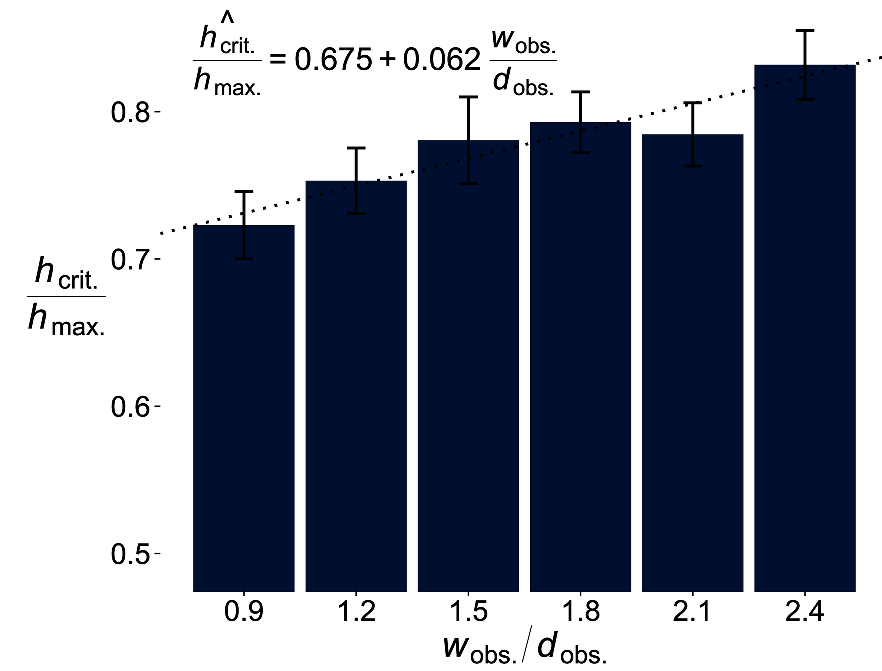

Figure 3. Mean critical (scaled) obstacle height for each (scaled) obstacle -width condition. Error bars show standard errors. The dotted line and equation show the results of a simple linear regression.

We ran mixed-effect linear regressions on these critical heights, with the aim of determining scaling relationships for the two actions. Tested individually, all three potential scaling factors for the stepping-over affordance (hip height, knee height, and maximum afforded height) significantly improved the regression by roughly the same amount, $X^2(1) \approx 8$, $p < .001$.

We tested the ratio of $w_{obs.}$ to $d_{obs.}$ as a potential π-number for the walking-around affordance. Its inclusion significantly improved model fit, $X^2(1) = 52.2$, $p < .001$. The corresponding random effect was not significant, $X^2(3) = 0.99$, $p > .05$.

The final model was

$$h_{\mathrm{crit.}} = -3.2 + 0.78\,h_{\mathrm{max.}} + 1.84\,\frac{w_{\mathrm{obs.}}}{d_{\mathrm{obs.}}} + u_i + \epsilon_{ij}$$

where u_i is the random-effect intercept for participant i and ϵ_{ij} is the measurement error for participant i in condition j.

Affordance-boundary analysis

As a secondary question, we investigated the relationship between anatomical measurements and participants' affordance boundaries for stepping over. A two-way ANOVA of maximum afforded height with predictors of hip height and knee height showed a significant main effect of hip height, $F(1, 16) = 9.64$, $p < .01$. Neither the main effect of knee height nor the interaction between the two measurements was significant, $p > .05$.

On average, a participant's observed affordance boundary for stepping over an obstacle was 74% of his or her hip height.

Discussion

As one might expect, participants were more likely to step over a shorter obstacle, and walk around a narrower obstacle. The tradeoff between the two alternatives can be understood as a competition between dimensionless quantities, or π-numbers.

The implicated scaling relationships can be varied. Here, we used an action-scaled π-number (obstacle height as a proportion of maximum height afforded), and a purely environment-scaled π-number (obstacle width as a proportion of distance to the obstacle). Note that the latter is related to the angle required to walk around the obstacle ($\theta_{obs.}$). Specifically, it is twice the tangent.

A future experiment should test the hypothesis that obstacle width is scaled by obstacle distance.

In reality, there are many more possible scaling relationships that could affect the selection between two actions. For example, we should investigate how subjective factors such as the participants' values are involved in action selection (see Hodges, 2007).

A synergetic model has been used to model selection between one- and two-handed grasping (Lopresti-Goodman et al., 2011). This model could be extended to describe selection between differently scaled actions (see Frank et al., 2010). To that end, a follow-up experiment testing for hysteresis is underway.

The origin of the regression coefficients is an important question. Despite being dimensionless, π-numbers may themselves require calibration. Alternatively, we should seek out scaling relationships with similar properties. For example, our π-number for stepping-over ranges from zero (no extra effort) to one (impossible). Our π-number for walking-around has the same interpretation of zero, but the action remains possible as long as the π-number is finite.

We speculate that a complete account of action selection will involve higher-order π-numbers.

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Further information

This research was supported by NSF Grant BCS-1344725 (INSPIRE Track 1).

Presented July 15, 2015 at the 18th International Conference on Perception & Action, University of Minnesota.

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