EXAMINING THE EFFECTIVENESS OF DECISIONS WHEN RECALIBRATING PERCEPTION OF ACTION POSSIBILITIES

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By

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A capstone project submitted for
Graduation with University Honors

June 8, 2018

University Honors
University of California, Riverside

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Abstract

When an observer's motor abilities are altered, affordance perception is uncalibrated, and motor errors are more likely to occur. For example, when wearing a backpack, observers' affordance perceptions are uncalibrated with respect to detecting whether a narrow doorway affords squeezing through. Practice--that is, attempting to squeeze through the doorway--is the only exploratory behavior sufficient for recalibrating perception in this task, but it is unclear whether people intuitively know that they need to practice in order to recalibrate. To this end, the current study allowed participants (n = 90) to engage in spontaneous practice. Additional goals were to determine whether spontaneous practice facilitates recalibration as efficiently as when practice is forced and to examine observers' confidence about their affordance perceptions. Our findings indicate that observers lack knowledge about how to explore in the doorway squeezing task. Spontaneous practice was found to be less efficient than forced practice, and observers appeared overconfident in their perceptions of their affordances for squeezing through the doorway prior to engaging in forced practice. Implications for future work include research to understand adults' knowledge about which exploratory behaviors facilitate recalibration of affordance perception for other tasks.

Keywords: affordance perception, recalibration, spontaneous exploration, practice

Acknowledgments

I thank John Franchak for his unparalleled support and guidance as my undergraduate mentor, and Jenna Monson for her invaluable help throughout this project. Thanks also to Emily Cortez, Marisela Martinez, Alex Rendon, and Janene Soto for their assistance with data collection and coding. This project was supported by funding from a UCR Chancellor's Research Fellowship awarded to the author (2017-2018 cohort).

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An *affordance* refers to the fit between an actor's physical properties and those of their surroundings, that allows certain actions to be taken (Franchak, 2017; Gibson, 1979; Mark, 1987; Warren, 1984). In moving through and interacting with the environment, people rely on affordance perception to accomplish certain tasks while avoiding adverse motor errors, such as accidental injury or damage to property (Franchak, 2017). Affordance perception—the detection of perceptual information about which actions are possible versus impossible—relies on a variety of information sources (Franchak, 2017). People need to acquire relevant perceptual information for perceiving affordances such that their perceptions are calibrated with respect to their actual abilities (Mark, Balliett, Craver, Douglas, & Fox, 1990). The extant literature offers many examples of commonplace affordances, including standing on and walking on slanted surfaces (Fitzpatrick, Carello, Schmidt, & Corey, 1994; Gibson, 1979; Kinsella-Shaw, Shaw, & Turvey, 1992), climbing and sitting on stairs (Mark, 1987; Mark et al., 1990; Stoffregen, Yang, & Bardy, 2005), passing under barriers (Stefanucci & Geuss, 2010; Stoffregen, Yang, Giveans, Flanagan, & Bardy, 2009; van der Meer, 1997; Wagman & Malek, 2008), and passing through doorways (Franchak, 2017; Franchak & Adolph, 2014; Franchak & Somoano, 2018; Franchak, van der Zalm, & Adolph, 2010; Warren & Whang, 1987; Yasuda, Wagman, & Higuchi, 2014).

Affordance perception is often studied in the context of perceptual *recalibration*. When properties of an observer or of their environment are altered, observers' perceived affordances become uncalibrated with respect to their actual affordances. Following such alterations to their motor abilities, observers must recalibrate—that is, adapt—their perceptions to reflect their actual current abilities (Franchak, 2017). For instance, when observers' torso widths increase after putting on a 12 cm-thick backpack, their affordance perception judgments for squeezing sideways through a narrow doorway have a mean absolute error (the absolute value of the differences between perceived and actual affordances) of 6.64 cm (Franchak, 2017). By contrast, observers who do not experience any alteration to their bodies before judging their abilities to squeeze through a doorway have a mean absolute error of only 3.11 cm (Franchak et al., 2010). In the doorway squeezing task, observers whose motor abilities have been altered display affordance perceptions that are uncalibrated to a greater degree than when no body alterations are made, so they have a greater need for perceptual recalibration.

An ongoing aim of affordance research is to elucidate the perceptual underpinnings that facilitate perceptual recalibration of affordances. Mark and colleagues (1990) found evidence that affordance perception, whether under novel or familiar conditions, requires *exploratory action* to generate necessary perceptual information. Specifically, they found that, after observers' height had increased by the addition of wooden blocks worn on the feet, observers' perceptions of their affordance for sitting on a riser quickly recalibrated. However, recalibration occurred only for observers who were permitted to make bipedal postural movements and produce optic flow, thus generating eyeheight-scaled information about their altered affordances for sitting (Mark et al., 1990). Eyeheight-scaled information through postural sway has also been found to facilitate recalibration for other affordances, including bipedal climbing (Mark, 1987) and passing under barriers (Marcilly & Luyat, 2008; Wagman & Malek, 2008), indicating that multiple disparate affordances require exploratory action for perceptual recalibration to occur. Conversely, recalibrating perception of different affordances may involve the acquisition of different types of perceptual information generated by different exploratory actions (Franchak, 2017). For instance, recalibrating affordances for climbing risers requires eyeheight information generated through postural movements (Mark, 1987), whereas recalibrating affordances for squeezing through doorways requires feedback information generated through practice (Franchak & Somoano, 2018).

Observers must explore to recalibrate their perceptions of various affordances, but little is known about whether people know that exploration is necessary for recalibration. In most recalibration studies, participants are assigned to treatment conditions that specify and restrict their exploratory experiences—that is, observers engage in *forced exploration*. Rather than specifying the types of forced exploration in which participants are to engage, allowing observers to engage in *spontaneous exploration* would allow researchers to examine the exploratory techniques observers believe play a role in recalibrating affordance perceptions. Some past work, and especially research on infant affordance perception, has observed spontaneous exploration by allowing participants to explore freely (Franchak & Adolph, 2012; Kretch & Adolph, 2016). For instance, research with infants has discovered that they engage in organized, spontaneous exploratory behaviors, including visual exploration, exploratory gait modifications, and haptic exploration, when deciding whether a bridge affords crossing (Kretch & Adolph, 2016), and exploratory practice when deciding whether a doorway affords squeezing through (Franchak & Adolph, 2012). While such research has not investigated whether infants' spontaneous exploratory actions facilitate recalibration of their affordance perceptions, it has provided a methodological framework that can be used to test whether adults spontaneously explore in the ways that have been empirically shown to facilitate recalibration.

However, the exploratory actions that facilitate perceptual recalibration for one affordance may be insufficient or unnecessary for recalibration for another affordance. For example, exploratory practice in the absense of eyeheight information has been found to be insufficient for perceptual recalibration of affordances for sitting (Mark et al., 1990). By contrast, practice has repeatedly been found to facilitate perceptual recalibration of one's affordance for squeezing through doorways (Franchak, 2017; Franchak & Adolph, 2014; Franchak & Somoano, 2018; Franchak et al., 2010). Similarly, exploratory actions other than practice have been found to be insufficient for recalibrating perception in the doorway squeezing task after putting on a backpack (Franchak, 2017). For instance, locomotion and pressing the backpack against a surface are ineffective means of exploration in that they fail to facilitate perceptual recalibration (Franchak, 2017). Practice effectively facilitates recalibration in this task by generating necessary feedback information of both success and failure experiences during attempts to squeeze through the doorway (Franchak & Somoano, 2018). Therefore, every affordance requires specific exploratory actions for recalibration, while other forms of exploration are, to this end, ineffective. This has significant implications for observers, who must discriminate between tasks and engage in the appropriate (i.e., most effective) exploratory action to produce calibrated perceptions of their abilities for each particular task. Since recalibration research has tended to limit observers' abilities to engage in spontaneous exploration, it remains unclear whether people know which exploratory actions are needed to facilitate perceptual recalibration for different affordances.

Current Study

Our central goal was to determine whether adults intuitively know which exploratory actions are necessary for perceptual recalibration of a widely-studied affordance—squeezing through doorways. Thus, the current study differed from past work in that we allowed participants to engage in spontaneous exploration. Specifically, we observed participants' spontaneous exploratory actions to determine the extent of their knowledge that practice is necessary for perceptual recalibration of their affordances for squeezing through doorways. Observers' knowledge of the need for practice in this task was measured by their decisions to engage in either effective (i.e., practice) or ineffective forms of spontaneous exploration.

The *exploration phase* was designed to elicit behaviors which participants presumably believed were valuable for recalibrating their affordance perceptions for the squeezing task. Spontaneous exploration was observed by coding video footage of each session. Spontaneous exploratory actions were partially guided by the experimental condition to which each participant was assigned. The *practice-allowed* and *practice-prohibited* conditions were designed to assess differences in participants' spontaneous exploratory behaviors when practice, the only effective means of recalibration, was or was not a viable option, respectively. The *practice-reward* condition, which also allowed spontaneous practice, was designed to ensure that participants were sufficiently motivated to achieve perceptual recalibration by offering to reward those whose perceptual judgments closely resembled their actual abilities.

A secondary goal of the current study was to test whether spontaneous practice facilitates recalibration of affordance perception as efficiently as forced practice has in past work (Franchak, 2017; Franchak & Somoano, 2018). To this end, participants' affordance perception was measured at three time points during the study: prior to spontaneous exploration, after engaging in spontaneous exploration, and after experiencing forced practice (i.e., practicing squeezing through doorways per the experimenter's instruction). If spontaneous and forced practice are equally efficient at facilitating perceptual recalibration, we would expect participants' perceptions to recalibrate following spontaneous practice, but not to recalibrate further following forced practice. Alternatively, participants who choose not to practice or who are prohibited from practicing would not be expected to recalibrate following spontaneous exploration, but would be expected to recalibrate following forced practice.

The *forced doorway fitting practice phase* served two purposes: to provide participants with practice experience and to allow the experimenter to obtain a measurement of each participant's actual affordance threshold. We calculated the error of each participant's affordance judgments with respect to their actual affordance threshold. Therefore, the degree to which participants' affordance perceptions were uncalibrated or recalibrated were expressed in terms of the differences between their perceptual judgments and their actual affordance threshold.

Finally, our third research goal was to ascertain whether observers detect changes in their affordance perceptions. To this end, at each of the three judgment phases, participants self-reported their confidence that their affordance perception judgments were proximal to their actual affordance thresholds. Thus, we were able to observe whether participants reported being able to detect that their affordance perceptions were not calibrated prior to spontaneous exploration, as well as whether their perceptions had recalibrated following spontaneous exploration and/or forced practice.

Method

Participants and Design

Participants were 90 undergraduate college students (54 female, 36 male), aged 16.6 to 31.4 years (M = 19.8, SD = 1.9). The data from 12 additional participants were excluded: for failure to understand or follow instructions during data collection (n = 10), for technological issues (n = 1), and for asking to withdraw their participation in the study (n = 1). All participants enrolled in the study for course credit through the research participation subject pool used by the psychology department at the University of California, Riverside. Due to height constraints for walking through the doorway apparatus, those who were taller than 190.5 cm were ineligible for participation in the study. Participants were also required to have normal or corrected-to-normal vision and to be able to walk without assistance.

Thirty participants were randomly assigned to each of three experimental conditions: practice-prohibited (17 female, 13 male), practice-allowed (22 female, 8 male), and practice-reward (15 female, 15 male). Each participant was run in the study individually.

Apparatus

The doorway apparatus and backpack were the same that were used in previous work (Franchak, 2017; Franchak & Somoano, 2018). As pictured in Figure 1, a freestanding metal framework (213.0 cm tall by 280.0 cm wide) provided a track (C) on which a sliding door (A) was mounted. A stationary panel (B; 182.0 cm tall by 62.0 cm wide) on one side of the structure formed a surface perpendicular to the sliding door. The doorway was 191.1 cm tall from the floor to the track on which the door was mounted, and when opened completely, was 70.0 cm wide. During the course of each session, the experimenter manipulated the width of the doorway while standing behind the apparatus, out of sight of the participant. A concealed monitor displayed readings from a measurement camera, allowing the experimenter to accurately adjust the width of the doorway in 0.10 cm increments. The door was equipped with a locking mechanism, which ensured that the doorway remained at the same width while participants attempted to squeeze through it.

Three cameras mounted around the room captured video and audio recordings for subsequent video coding of aspects of participants' exploratory behaviors, including the approximate distance from the doorway participants approached during each exploration trial. For this purpose, strips of colored tape on the ground (see Figure 1) marked the starting line (D) at a distance of 3.5 m from the doorway, as well as distances of 3 m (E), 2 m (F), and 1 m (G) from the doorway.

Participants wore a backpack throughout the duration of the study. The backpack was 12.0 cm in depth, weighed 1.1 kg, and contained a stack of rigid cardboard to prevent compression as participants squeezed through the doorway. The backpack was secured with two straps (chest and waist) to ensure that it remained centered on participants' backs.

Procedure

At the start of the approximately 45-minute-long session, participants put on the backpack and secured its straps to ensure that it remained in place on the back. Participants began every trial of each phase by standing behind the starting line. Participants in all conditions completed five experimental phases in the following order: 1) judgment 1 (J1); 2) exploration; 3) judgment 2 (J2); 4) forced doorway fitting practice; and 5) judgment 3 (J3).

Affordance judgment phases. The affordance judgment phases (J1-J3) measured participants' affordance perception at various levels of experience with squeezing through the doorway. Thus, the procedure was identical for each of the three phases. J1 served as a pretest before any exploratory experience had been incurred, and J2 served as a posttest following spontaneous exploration in the exploration phase. J3 served as a posttest following the forced doorway fitting practice phase, thus presenting us an opportunity to replicate Franchak's (2017) findings that forced practice facilitates perceptual recalibration. As in past work (Franchak & Somoano, 2018), perceived affordances were measured using a method of limits (MoL)—a procedure in which observers view a gradually increasing or decreasing stimulus and indicate the point at which an action (e.g., squeezing through the doorway) transitions from impossible to possible, or vice versa (Warren & Whang, 1987). Each affordance judgment phase consisted of four MoL trials. Because past work found no changes in affordance judgments over the course of 24 successive MoL pretest trials (Franchak & Somoano, 2018), four trials were thought to be sufficient to accurately determine participants' affordance perception at each phase.

During each affordance judgment trial, the participant stood at the starting line and the experimenter gradually moved the door in one direction until the participant said that they believed that the doorway was the smallest they could successfully squeeze through the doorway while wearing the backpack (i.e., that it resembled their actual affordance threshold). Though they were not permitted to attempt to fit through the doorway during the judgment phases, participants were informed that only a complete fit through the doorway in a sideways orientation, with the backpack against the doorway's stationary panel, would constitute successful passage through the doorway. The direction of the door's movement alternated between ascending (closed to open) on odd-numbered MoL trials, and descending (open to closed) on even-numbered MoL trials.

Immediately after the fourth MoL trial in each phase, participants rated their confidence that the current doorway (i.e., their most recent MoL judgment) was in fact the smallest doorway that they could fit through. As in past work (e.g., Fitzpatrick et al., 1994), confidence ratings were reported using a Likert-type scale ranging from 1 (not at all confident) to 7 (extremely confident).

To ensure that participants were sufficiently motivated to make effective exploratory decisions in the exploration phase, those in the practice-reward condition were offered a cash reward for attaining sufficient perceptual recalibration by J2. All participants in the practice-reward condition had been informed at the start of the study that a mean judgment error of no more than ± 2.5 cm in J2 would be rewarded with five dollars at the end of the study.

Exploration phase. In the exploration phase, participants were presented with a wide range of doorway widths and were permitted to explore in ways they believed would help decrease the error of their J2 affordance judgments (i.e., alter their J2 judgments such that they more closely resembled their actual affordance threshold). Thus, we observed the ways in which adults spontaneously explored when deciding whether passage through a doorway was possible. Participants completed 3 blocks of 10 exploration trials (30 trials total). Each block was composed of ten different doorway widths ranging from 16 cm to 43 cm, in 3 cm increments. All participants had a mean affordance threshold within this range while wearing the backpack. In each block, all 10 doorway widths were randomly distributed among the 10 trials.

Participants began each trial at the starting line, facing away from the apparatus so that they would not see the doorway change between trials. At the start of each trial, participants turned, viewed the doorway, and delivered a verbal ‘yes’ or ‘no’ response, indicating whether they believed they could fit sideways through the doorway while wearing the backpack. Participants were informed that, to help them accurately determine whether passage through each doorway was possible or impossible, they were permitted to explore in any way they chose prior to responding ‘yes’ or ‘no.’ Several exploratory behaviors, were prohibited: across conditions, participants were not permitted to manually adjust the width of the doorway or to remove the backpack. In addition, those in the practice-prohibited condition were not permitted to practice (i.e., to make any attempt to fit through or move past the doorway with any part of the body). Therefore, the instructions for this phase varied slightly according to condition, but the methods with which the phase was conducted were identical across conditions. Participants were reminded that no exploratory action was required prior to responding for any trial, but that any action was allowed, with the exceptions detailed above. After delivering each ‘yes’ or ‘no’ response, participants were asked to rate their confidence that their response was correct, using the same scale of 1-7 that was used in the affordance judgment phases.

Forced doorway fitting practice phase. Conducted between J2 and J3, the forced doorway fitting practice phase was designed to measure participants' actual abilities as a basis of comparison between the affordance judgments made in J1, J2, and J3. Participants completed 15 forced-practice trials, during which they attempted to squeeze through doorways of various widths. The first doorway for all participants was 25 cm wide. Subsequent doorway widths were administered using a staircase method calculated by a MATLAB script: successful attempts to fit through the doorway were followed by a doorway measuring 2 cm narrower. Unsuccessful attempts to fit through the doorway were followed by a doorway measuring 1.5 cm wider. Thus, we were able to quickly scale the forced-practice doorway widths such that they were proximal to each participant's affordance threshold while wearing the backpack, providing participants with both success and failure feedback information. Affordance threshold for squeezing was defined as the average doorway width each participant could fit through on 50 percent of trials, and was calculated from the proportion of forced practice trials that resulted in a successful attempt at squeezing through the doorway.

Data Coding and Analysis

A custom MATLAB script was used both to provide the experimenter with the appropriate doorway setting for each trial and to collect data from participants' responses and their success and failure outcomes of forced practice. Subsequent video coding was used to collect data of participants' spontaneous exploratory behaviors. Using Datavyu software (www.datavyu.org), a primary coder scored each participant's exploratory behaviors during 100 percent of exploration trials, and a reliability coder scored approximately 25 percent of trials (7 out of 30 trials) for each participant. Our coding protocol followed closely to other perception-action studies that used similar observational paradigms (see Kretch & Adolph, 2016). We developed codes for each of the common exploratory behaviors adults used according to preliminary observations of the doorway squeezing task.

Response latency. Latency (in seconds) was coded by scoring the onset and offset frames for each trial. Trial onset was defined as the frame at which the participant began to turn to face the doorway (coded using visual recording), and trial offset was defined as the frame at which the participant began to deliver a 'yes' or 'no' response (coded using audio recording). Latency scores between primary and reliability coders were positively correlated: $r(630) = 1.00$, $p < .001$. Participants' actions occurring between trials (after responding 'yes' or 'no' for one trial and before turning to face the doorway on the next trial) were considered extraneous and were not coded.

Approach distance. We coded the distance from the doorway participants approached using the strips of colored tape on the floor. We defined the distance approached as the furthest line beyond which participants stepped with one entire foot. Coders agreed on the distance participants approached in 98.9% of trials (Kappa = .98).

Stand sideways. Participants were said to have turned sideways if they stood with both feet planted parallel to the apparatus for a duration of at least 500 milliseconds. Coders agreed on whether participants stood sideways on 96.2% of trials (Kappa = .92).

Touch backpack. Participants were said to have touched the backpack if they used their hands to reach behind their backs to touch any part of the backpack, not including its straps. Coders agreed on whether participants touched the backpack on 99.0% of trials (Kappa = .95).

Press backpack. Participants were said to have pressed the backpack if there was any contact between the back of the backpack and any surface, including the wall and the apparatus (e.g., the participant leaning backwards against the wall to gauge compressibility of the backpack). Coders agreed on whether participants pressed the backpack on 96.7% of trials (Kappa = .93).

Touch door. Participants were said to have touched the door if their hands came into contact with any part of the doorway apparatus. Coders agreed on whether participants touched the door on 97.6% of trials (Kappa = .78).

Practice. Participants in the practice-allowed and practice-reward conditions were said to have practiced if they fit at least one shoulder through the doorway. Coders agreed on whether participants practiced on 98.1% of trials (Kappa = .97).

Planned Analyses

Perceptual judgment error and confidence were each to be assessed using a 3 × 3 ANOVA, where the within-subjects factor was phase (J1, J2, and J3) and the between-subjects factor was condition (practice-prohibited, practice-allowed, and practice-reward). Rates of spontaneous exploration and exploration-phase response latency were calculated by distributing trials among 5 bins, each of which contained doorway widths within a particular range with respect to each participant's actual affordance threshold. Thus, spontaneous exploration and response latency were to be assessed using a 5 × 3 ANOVA, where the within-subjects factor was bin (much smaller, moderately smaller, near threshold, moderately larger, and much larger) and the between-subjects factor was condition (practice-prohibited, practice-allowed, and practice-reward). Similarly, rates of spontaneous practice per bin were to be assessed using a 5 × 2 ANOVA, where the within-subjects factor was bin (much smaller, moderately smaller, near threshold, moderately larger, and much larger) and the between-subjects factor was condition (practice-allowed and practice-reward). See the Results section on qualities of exploration for a full description of the bins used in the analyses just mentioned. All pairwise comparisons between conditions were conducted using the Sidak correction to rectify the problem of multiple comparisons (Šidák, 1967).

Results

The goals of the current study were to discern the extent to which adults know that exploratory practice is necessary to facilitate perceptual recalibration of their affordances for squeezing through doorways, to determine whether spontaneous practice recalibrates perception as efficiently as forced practice, and to examine people's confidence about their affordance judgments. To these ends, we conducted 3 sets of analyses.

Qualities of Exploration Relate to Actual Affordance Thresholds

Video coders scored the exploration block for response latency, approach distance, and whether participants stood sideways, touched the backpack, touched the door, pressed the backpack, and practiced. We used binned analyses to compare rates of these behaviors at various doorway widths, relative to each participant's actual affordance threshold. We distributed the ten doorway widths among five bins: much smaller than threshold, moderately smaller than threshold, near threshold, moderately larger than threshold, and much larger than threshold. Since the bins were scaled to participants' actual threshold, the number of doorway widths in each bin depended on each participant's threshold. For any given participant, bin 3 contained trials for which the doorway width was *near threshold* (less than or equal to 1.5 cm away from threshold). Bins 2 and 4 contained trials for which the doorway width was *moderately smaller* or *moderately larger than threshold*, respectively (greater than 1.5 cm and less than 6 cm away from threshold). Bins 1 and 5 contained trials for which the doorway width was *much smaller* or *much larger than threshold*, respectively (greater than or equal to 6 cm away from threshold). Due to several exceptionally low affordance thresholds, two participants did not have any trials in bin 1. Their data were therefore excluded from all following analyses of spontaneous exploration (*n*s were 30, 29, and 29, for the practice-prohibited, practice-allowed, and practice-reward conditions, respectively).

Spontaneous exploration. First, we examined the spontaneous behaviors in which participants engaged across all exploratory techniques, excluding practice since one third of participants were prohibited from practicing. Figure 2 displays the mean number of spontaneous exploratory actions in which participants (n = 88) engaged for doorways of various widths relative to each participant's actual affordance threshold, and lists means and standard deviations collapsing across conditions. A 5 Bin × 3 Condition (practice-prohibited, practice-allowed, practice-reward) ANOVA revealed a significant main effect of bin, $F(4, 340) = 95.42$, $p < .001$, $\eta_p^2 = .53$. There was no significant main effect of condition, $F(2, 85) = .29$, $p = .75$, $\eta_p^2 = .01$, and no significant interaction of bin and condition, $F(8, 340) = 1.77$, $p = .08$, $\eta_p^2 = .04$. Thus, the number of spontaneous exploratory actions in which participants engaged during each trial was determined by the doorway size relative to their individual affordance thresholds. Quadratic contrasts of bin revealed a significant quadratic trend for exploration across conditions, $F(1) = 208.39$, $p <.001$, $\eta_p^2 = .71$, indicating that all participants explored more frequently when doorways were near their individual affordance thresholds, and less frequently when doorways were much smaller or much larger than threshold.

Response latency. Latency—the time participants took to view and explore a given doorway, and say whether squeezing through it is possible—has important implications for when and how observers choose to engage in spontaneous exploratory behaviors. Given that participants were expected to explore more frequently for doorways that were near threshold, it followed that, across conditions, response latency would be longest for near-threshold doorways. Figure 3 displays the mean latency, in seconds, of participants' (*n* = 88) exploration trials for doorways of various widths relative to each participant's actual affordance threshold, and lists means and standard deviations collapsing across conditions. As in the analyses of overall exploration, a 5 Bin × 3 Condition (practice-prohibited, practice-allowed, practice-reward) ANOVA revealed a significant main effect of bin, $F(4, 340) = 47.22$, $p < .001$, $\eta_p^2 = .36$, but no significant main effect of condition, $F(2, 85) = 1.73$, $p = .18$, $\eta_p^2 = .04$, and no significant interaction of bin and condition, $F(8, 340) = .97$, $p = .46$, $\eta_p^2 = .02$. Thus, the amount of time participants took to deliver their verbal response for each trial was determined by the doorway size relative to their individual affordance thresholds. Quadratic contrasts of bin revealed a significant quadratic trend for latency, $F(1) = 103.62$, $p < .001$, $\eta_p^2 = .55$, indicating that all participants took more time to explore when doorways were near their individual affordance thresholds, and less time when doorways were much smaller or much larger than threshold.

Spontaneous practice. Lastly, spontaneous practice during the exploration phase was also expected to be more frequent for doorways that were near threshold and less frequent for those that were much smaller or much larger than threshold. Figure 4 displays the mean number of trials in which participants engaged in spontaneous practice for doorways of various widths relative to each participant's actual affordance threshold, and lists means and standard deviations collapsing across conditions. Analyses of spontaneous practice were limited to the two conditions in which practice was permitted (*n* = 58). A 5 Bin × 2 Condition (practice-allowed, practice-reward) ANOVA revealed a significant main effect of bin, $F(4, 224) = 59.04$, $p < .001$,

η_p^2 =.51. There was neither a significant main effect of condition, $F(1, 56) = .02$, $p = .89$, $\eta_p^2 < .001$, nor a significant interaction of bin and condition, $F(4, 224) = .36$, $p = .84$, $\eta_p^2 = .01$. Therefore, the frequency of spontaneous practice during the exploration phase was determined by the size of the doorway relative to participants' individual affordance thresholds. Quadratic contrasts of bin revealed a significant quadratic trend for practice, $F(1) = 85.22$, $p < .001$, $\eta_p^2 = .60$, indicating that all participants practiced more frequently when doorways were near their individual affordance thresholds, and less frequently when doorways were much smaller or much larger than threshold.

Judgment Error

For each participant ($n = 90$), judgment error at each phase (J1 – J3) was calculated by taking the absolute value of the difference between their mean MoL affordance judgment and their actual affordance threshold (measured in the forced doorway fitting practice phase). Figure 5 displays the mean judgment error for each condition at each judgment phase. A 3 Phase (J1, J2, J3) × 3 Condition (practice-prohibited, practice-allowed, practice-reward) ANOVA on judgment error revealed a main effect of phase, $F(2, 174) = 51.30$, $p < .001$, $\eta_p^2 = .37$, with judgment error decreasing by phase. There was no significant main effect of condition, $F(2,87) = 3.00$, $p = .06$, $\eta_p^2 = .07$. As expected, there was a significant interaction of phase and condition, $F(4,174) = 2.59$, $p = .04$, $\eta_p^2 = .06$, indicating that condition differentially moderated changes in participants' perceptual judgment errors between phases.

To follow up on the interaction of phase and condition, we conducted pairwise comparisons between conditions at each phase. There were no significant differences in judgment error between conditions at J1, before participants had engaged in any exploratory actions (ps > .88). Participants who were then allowed to practice spontaneously were expected to recalibrate at J2, while those for whom practice was prohibited were not predicted to recalibrate. Pairwise comparisons of judgment error between conditions supported these predictions by revealing that, participants who were permitted to practice had significant (*ps* < .04) decreases in error from J1 (practice-allowed: *M* = 7.31, *SD* = 4.95; practice-reward: *M* = 7.60, *SD* = 4.74) to J2 (practice-allowed: *M* = 5.08, *SD* = 3.02; practice-reward: *M* = 4.74, *SD* = 4.01). There was no significant difference in J2 accuracy between the practice-allowed and practice-reward conditions (*p* = .98). Additionally, participants in the practice-prohibited condition did not show a significant (*p* = 1.00) decrease in error from J1 (*M* = 8.13, *SD* = 4.75) to J2 (*M* = 8.06, *SD* = 4.17), and their J2 error was significantly greater than that of the groups for which practice was permitted (*ps* < .01). Across conditions, error significantly (*ps* < .05) decreased from J2 to J3 (practice-prohibited: *M* = 2.94, *SD* = 1.96; practice-allowed: *M* = 3.23, *SD* = 2.19; practice-reward: *M* = 2.19, *SD* = 1.22), indicating that, following the opportunity for spontaneous practice, participants recalibrated less efficiently than when practice was forced. There were no significant differences in accuracy between conditions at J3, after forced practice had occurred (*p*s > .09).

Confidence

Participants verbally reported their confidence about their perceptual affordance judgments using a 1-7 Likert-type scale following the last MoL trial of each of the J1, J2, and J3 phases. Figure 6 displays trends in confidence by condition and phase. A 3 Phase (J1, J2, J3) × 3 Condition (practice-prohibited, practice-allowed, practice-reward) ANOVA revealed a significant main effect of phase, $F(2, 174) = 19.00$, $p < .001$, $\eta_p^2 = .18$, but not of condition, $F(2, 87) = .51$, $p = .60$, $\eta_p^2 = .01$. There was a marginally significant interaction of phase and condition, $F(4, 174) = 2.43$, $p = .05$, $\eta_p^2 = .05$.

Pairwise comparisons of phase by condition revealed patterns of confidence that differed according to condition. Participants for whom practice was prohibited reported no significant change in confidence (p = .22) between J1 (M = 5.03, SD = 1.03) and J2 (M = 5.33, SD = .92). They reported significantly higher confidence (p = .003) from J2 to J3 (M = 5.90, SD = .80) after forced practice had occurred. Participants in the practice-allowed condition reported being significantly less confident (p = .001) at J1, before spontaneous exploration (M = 4.87, SD = .97) than after, at J2 (M = 5.63, SD = 1.00), but their confidence following forced practice at J3 (M = 5.73, SD = .87) did not significantly differ (p = .91) from their J2 confidence ratings. Participants in the practice-reward condition showed no significant differences (ps > .22) in confidence ratings between J1 (M = 5.37, SD = .81), J2 (M = 5.73, SD = 1.20), or J3 (M = 5.67, SD = 1.16).

Discussion

In the present study, observers spontaneously explored more often and for longer periods of time when the doorway was near threshold or moderately larger than threshold—that is, when the task of perceiving one's affordances for squeezing through the doorway was difficult. In other words, we found that aspects of spontaneous exploration tracks task difficulty. We also found that spontaneous practice fails to facilitate perceptual recalibration as efficiently as when practice is forced, and that observers are overconfident in their perceptual judgments about their affordances before forced practice occurs.

Unawareness that Practice Facilitates Recalibration

Our results point to the conclusion that observers know when but not how to spontaneously explore. Frequency of exploration, response latency, and frequency of spontaneous practice all track task difficulty, indicating adept perception about when exploration is necessary. However, we found one unanticipated trend. Generally, exploring doorways that are much smaller or much larger than threshold is an unnecessary expenditure of energy, while exploring doorways that are near threshold has the propensity to provide useful feedback information about the observer's actual abilities, and is therefore a wise investment of energy (Franchak & Somoano, 2018). The notion of an optimal point of minimal energy expenditure in the context of an affordance task has been explored by Warren (1984). However, participants in the present study explored equally as frequently and for as long when doorways were moderately larger than their actual thresholds, as when they were near threshold. A possible explanation for this finding is that observers may have a perceptual bias for doorways that are larger than threshold, as they anticipate requiring more space to squeeze through than they actually need (Franchak, Celano, & Adolph, 2012).

While observers are fairly adept at knowing when to explore, they do not know that practice alone facilitates perceptual recalibration for squeezing through doorways. Across conditions, participants explored near-threshold doorways using methods other than practice. They engaged in ineffective exploratory methods whether or not practice was prohibited. Participants also engaged in ineffective spontaneous exploration even when offered a cash reward for perceptual recalibration, indicating that such behavior is not an issue of lack of motivation in the experiment, but rather an issue of lack of knowledge about the necessity of practice in this task.

Spontaneous Practice Inefficiently Facilitates Recalibration

We found that spontaneous practice does not facilitate perceptual recalibration of observers' affordances for squeezing through doorways as efficiently as forced practice. One explanation of this finding is that spontaneous practice is qualitatively different than forced practice. For instance, perhaps observers' perceptual bias for doorways that are moderately larger than threshold cause them to spontaneously practice only on doorways that are either possible or impossible, generating inadequate feedback information (i.e., only success or only failure feedback information). Alternatively, observers may generate the right types of feedback information through spontaneous practice, but for too few trials to facilitate recalibration as efficiently as when practice is forced. In the present study, participants spontaneously practiced, on average, less than once (M = .58) for each doorway that was within 1.5 cm of their actual affordance thresholds, whereas forced practice has been found to require as many as 5 trials to efficiently facilitate recalibration (Franchak & Somoano, 2018). While the precise reason for the comparative inefficiency of spontaneous practice is unclear, we were able to replicate Franchak's (2017) findings that forced practice efficiently recalibrates affordance perception for squeezing through doorways.

Overconfidence About Affordance Perception

An unanticipated finding of the current study was that confidence did not track affordance judgment error: Prior to experiencing forced practice, observers exhibited overconfidence in their perceptual affordance judgments. Specifically, all participants were overconfident prior to engaging in any exploratory behaviors, indicating that, across conditions, they were unaware that their initial affordance judgments differed from their actual affordance threshold. Also interesting is that observers who were permitted to practice spontaneously were not then more confident following forced practice. Reasonably, participants for whom spontaneous practice was prohibited were more confident following forced practice. It is possible that the scale we used to assess confidence experienced a ceiling effect, although this seems unlikely since the mean confidence rating at any judgment phase and across conditions was less than 6 out of 7. Together, these results suggest that observers lack intuition that their affordance judgments, in the absence of forced practice, are uncalibrated with respect to their actual abilities.

Limitations and Future Directions

The current study observed the ways in which adults spontaneously explore, to determine the extent of their knowledge that practice is necessary to facilitate perceptual recalibration of their affordances for squeezing through doorways. A potential inferential concern is that our procedure and interpretation relied on the assumption that observers will spontaneously explore in the ways they believe to be helpful to facilitate perceptual recalibration. However, we saw no *a priori* reason to suspect that participants would choose *not* to explore using the method(s) they believed would help recalibrate their perceptions, given their permissibility in the exploration phase. Future work should analyze self-report data about what exploratory actions adults believe to be useful for recalibrating their affordance perceptions.

Secondly, the current study grouped participants largely based upon whether practice was prohibited or allowed. It did not explore trends in exploration, recalibration, or judgment confidence when comparing groups based on the extent to which participants actually engaged in spontaneous practice. A related question is derived from our finding that spontaneous practice recalibrates perception less efficiently than does forced practice. Follow-up studies should explore quantitative and qualitative differences between the two forms of practice to discern the source of differences in recalibration.

Further work is needed to elucidate adults' knowledge about the effectiveness of spontaneous exploration during the doorway squeezing task. For instance, participants in the current study failed to efficiently recalibrate their affordance perceptions, even when they were explicitly allowed to practice as often as desired and when offered a cash reward for making judgments that could be improved precisely through such practice. It is possible that observers in affordance perception tasks are not motivated by the promise of a reward, but rather by fear of a consequence (Franchak & Adolph, 2012). Future studies should test whether the threat of a consequence (e.g. wasting energy, risking entrapment in an impossibly small doorway, or losing money) impacts observers' willingness to engage in spontaneous exploratory practice. Furthermore, the research questions addressed by the current study should be applied to other affordance perception and recalibration tasks. In particular, tasks for which recalibrating perception does not require practice, such as walking under barriers, should be explored to determine whether observers know how and when to explore when recalibrating perceptions of task-specific affordances.

Conclusion

Recalibrating perception of different affordances requires exploratory experience, but the form of exploration necessary to facilitate perceptual recalibration is task-specific. Our findings show that adult observers lack intuitive knowledge about how to explore when recalibrating perception of their abilities to squeeze through a narrow doorway. Self-report measures of confidence indicate that observers are not even aware that their perception merits recalibration to begin with. Our findings have implications for understanding and mitigating spontaneous exploratory behaviors that may lead to motor errors resulting in injury or damage to property. Future research will expand our understanding of how observers navigate their surroundings and explore their affordances such they are able to perceive the limits of their actual abilities.

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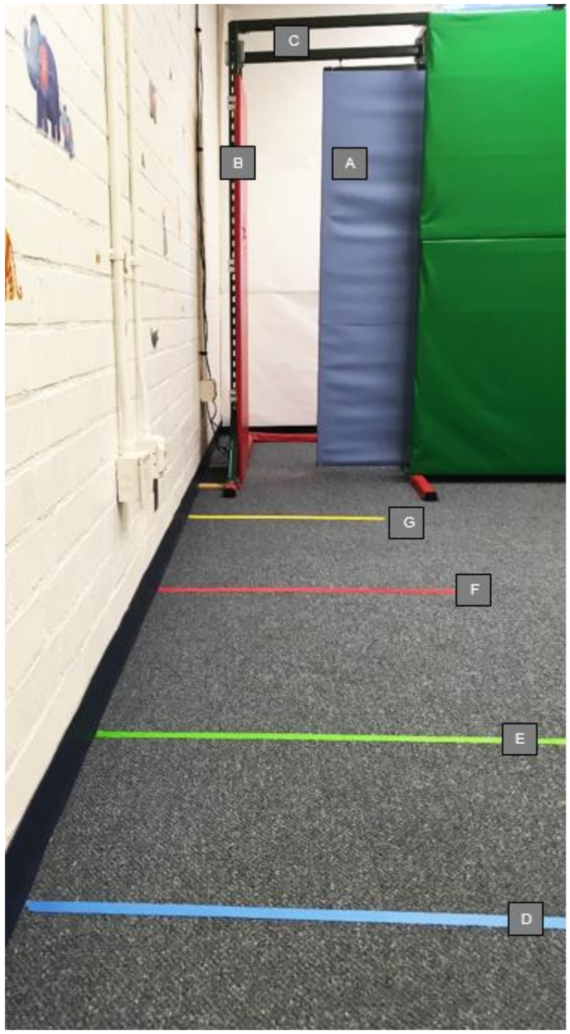

Figure 1. The adjustable doorway consisted of a sliding door (A) and a stationary panel (B). The door was mounted on an overhead track (C) and was equipped with a locking mechanism to prevent incidental movement of the doorway. Colored tape on the floor in front of the doorway marked the startling line (D) at 3.5 m from the doorway, as well as distances of 3 m (E), 2 m (F), and 1 m (G) from the doorway to allow video coding of exploratory approaching behaviors.

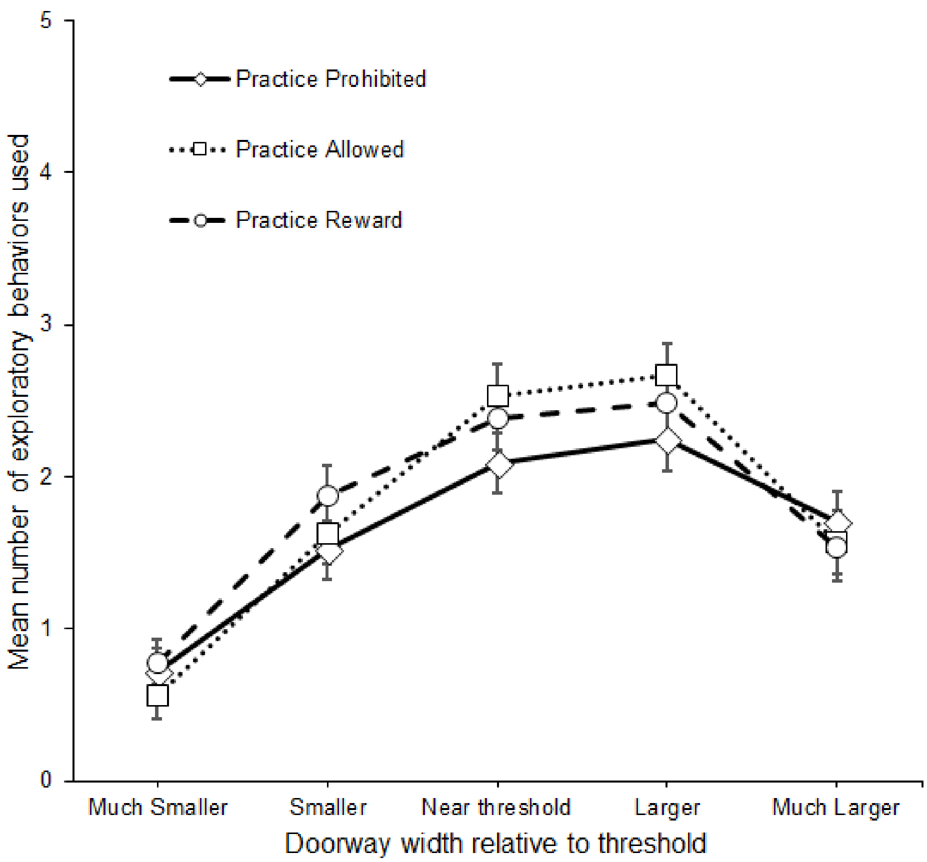

Figure 2. In the exploration block, participants across conditions (*n* = 88) spontaneously explored most frequently for doorways that were near threshold (bin 3; *M* = 2.33, *SD* =1.11) and moderately larger that threshold (bin 4; *M* = 2.46, *SD* = 1.13). Exploration was less frequent for doorways that were moderately smaller than threshold (bin 2; *M* =1.67, *SD* =1.05) and much larger than threshold (bin 5; *M* = 1.60, *SD* 1.09). Spontaneous exploration was least frequent for doorways that were much smaller than threshold (bin 1; *M* = .69, *SD* = .79).

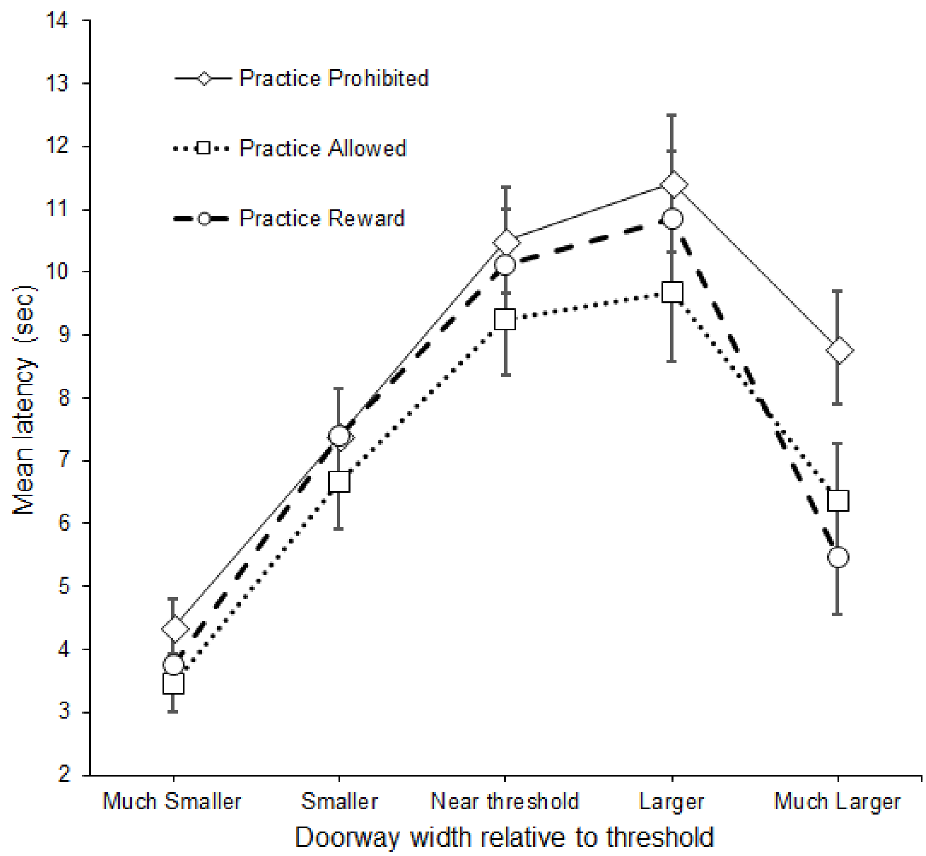

Figure 3. In the exploration block, participants across conditions (n = 88) took more time (response latency, in seconds) to decide whether a doorway afforded squeezing through for doorways that were near threshold (bin 3; M = 9.96, SD = 4.64) and moderately larger that threshold (bin 4; M = 10.65, SD = 5.87). Latency was shorter for doorways that were moderately smaller than threshold (bin 2; M = 7.25, SD = 4.07) and much larger than threshold (bin 5; M = 6.89, SD = 5.05). Response latency was the shortest for doorways that were much smaller than threshold (bin 1; M = 3.87, SD = 2.48).

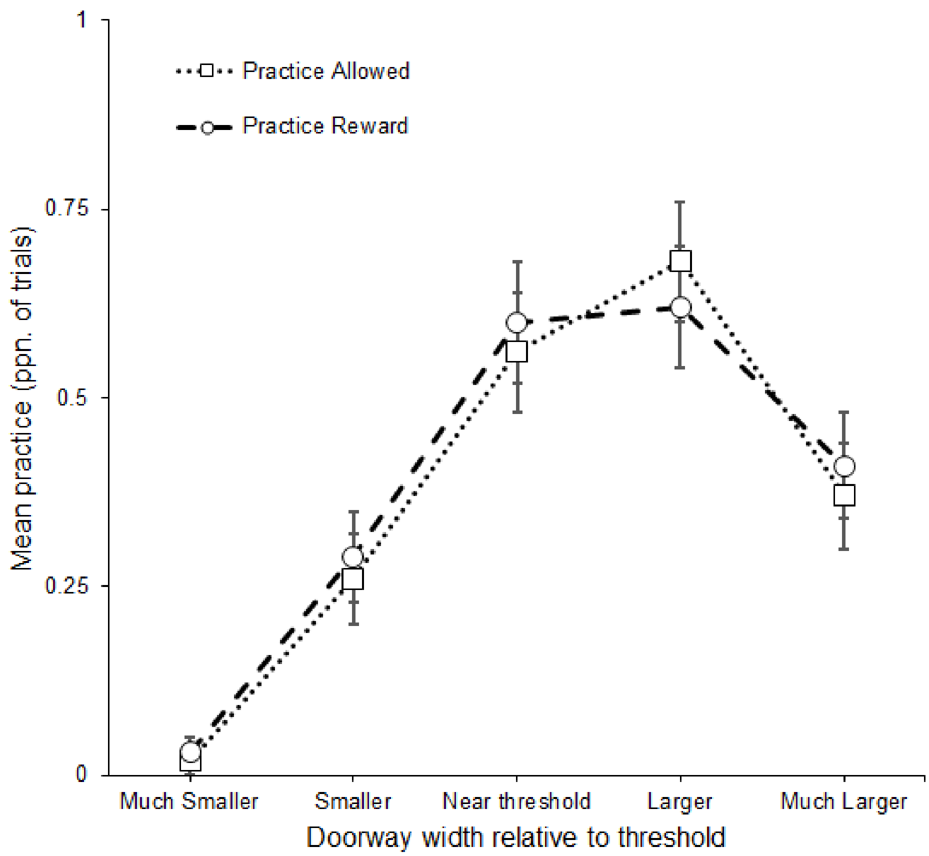

Figure 4. In the exploration block, participants in the practice-allowed and practice-reward conditions spontaneously practiced most frequently for doorways that were near threshold (bin 3; M = .58, SD = .42) and moderately larger that threshold (bin 4; M = .65, SD = .42). Practice was less frequent for doorways that were moderately smaller than threshold (bin 2; M = .28, SD = .31) and much larger than threshold (bin 5; M = .39, SD = .35). Spontaneous practice was least frequent for doorways that were much smaller than threshold (bin 1; M = .03, SD = .11).

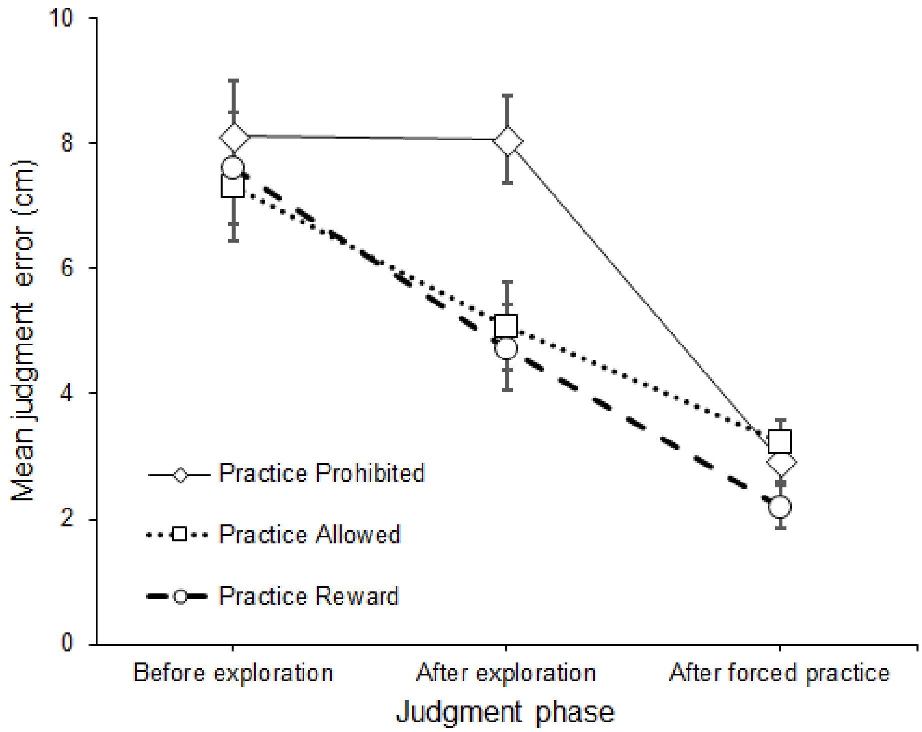

Figure 5. Judgment error was equal across conditions both before spontaneous exploration (J1) and after forced practice (J3). Participants in conditions for which spontaneous practice was allowed recalibrated their affordance perceptions following spontaneous exploration (J2). However, recalibration occurred across conditions between J2 and J3. This indicates that spontaneous practice facilitates perceptual recalibration less efficiently than does forced practice.

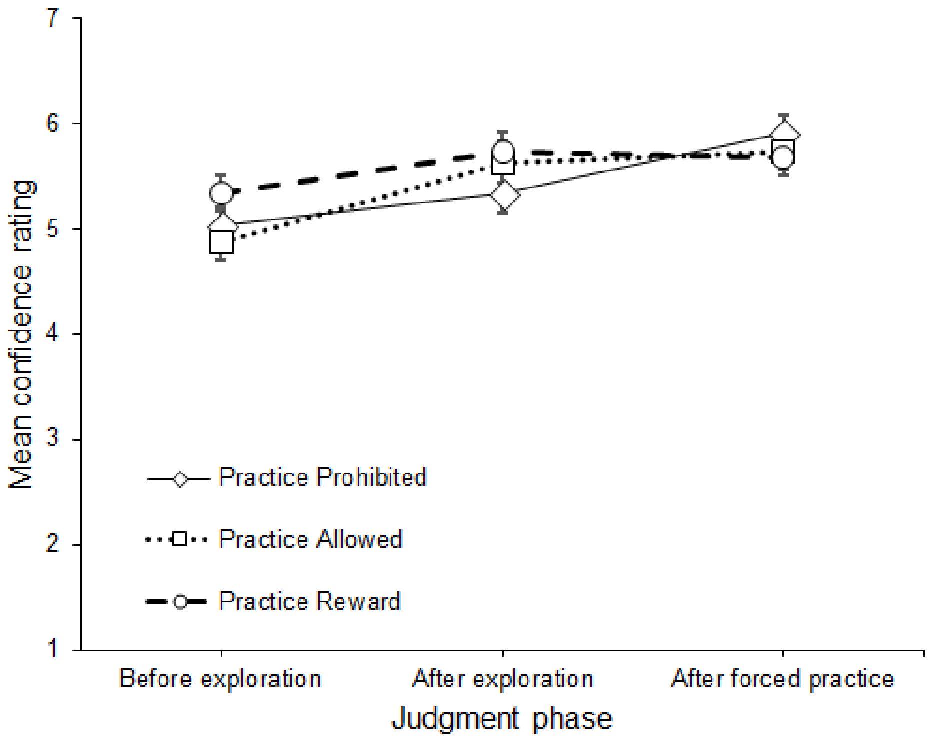

Figure 6. Participants across conditions were overconfident about their affordance perceptions both before and after spontaneous exploration (J1 and J2, respectively). Confidence did not track perception judgments. Participants remained appropriately confident about their recalibrated affordance perceptions after forced practice (J3).