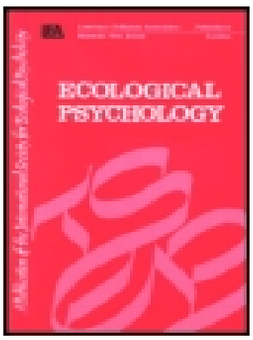

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REPORT

Experience Influences Affordance Perception for Low Crawling Under Barriers With Altered Body Dimensions

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ABSTRACT

We examined the role of experience in affordance perception for low crawling with altered body dimensions under barriers of different heights. Adults decided which of five backpacks (10–30 cm thick) they would be able to wear while low crawling under barriers. Participants were assigned to one of three experience conditions. Participants in the Pre/Post-choice experience condition crawled under the barrier before and after picking a backpack, participants in the Feedback condition crawled under the barrier after picking a backpack, but participants in the No Experience condition received no low-crawling experience. Past research suggests that pre-choice experience with low crawling under the barrier would lead to more accurate responses. Overall, participants in all three conditions scaled the height of the backpack to the barrier height. Pre-choice low-crawling experience strongly influenced backpack choices such that participants in the Pre/Post condition picked significantly smaller backpacks and produced fewer failures than participants in the other conditions. The results provide evidence that brief practice, in an unfamiliar posture, can lead to improvements in affordance perception.

KEYWORDS

decision making; load carriage; recalibration; practice

According to Gibson's (1979) ecological approach, affordances are possibilities for action that depend on the match between the body and environmental conditions. Individuals must recognize that changes to either the body or the environment may alter the affordance relationship—actions that were once possible may now be impossible. For instance, wearing a bulky winter coat or carrying large boxes limits which sized doorways one can safely pass through. To avoid mishaps and make adaptive decisions one must adjust their actions to account for new affordances. Perceptual information gleaned from proprioception and visual and tactile exploration can be used to inform motor decisions. Moreover, several lines of research show that experience enables individuals to make accurate decisions that match the limits of their abilities. The current study expands the literature on affordance perception by examining the role of experience in a different locomotor posture, specifically, low crawling under barriers while wearing a backpack.

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One well-studied paradigm in affordance research is the task of fitting through apertures of different sizes. Building on Warren and Whang's (1987) classic walking through apertures study, researchers have tested infants, toddlers, adults, pregnant women, and wheelchair users (e.g., Franchak & Adolph, 2012; 2014b; Higuchi, Cinelli, Greig, & Patla, 2006; Stefanucci & Geuss, 2010; van der Meer, 1997). Navigating through apertures is an ideal task because both sides of the affordance relationship are clearly represented and changes in either must be detected in order to safely pass through. Furthermore, researchers can easily manipulate the environment by altering the size, shape, pathway, material composition, or orientation, etc., of the to-be-fit opening. Researchers can manipulate the body in a variety of ways such as affixing objects to individuals, asking them to hold objects, and having them navigate vehicles, etc.

Wearing a backpack is a common way to alter body dimensions and change affordances. Depending on the size and position, a backpack shifts the wearer's center of mass, expands their physical dimensions and weight, and involves an additional expenditure of energy to maintain balance and continue movement. Wearers may also incorporate dynamic information about strength, compressibility, and flexibility like they do with other actions (Ishak, Adolph, & Lin, 2008; Konczak, Meeuwson, & Cress, 1992). Successfully fitting through doorways, crowded hallways, and congested classrooms with a backpack requires taking into account both the person and backpack's dimensions. The problem is not trivial because visual information about the backpack and the person's body become limited once the backpack is on the back. Furthermore, proprioception may not provide enough information since the size and weight of the load do not provide consistent data because a light load can be large and bulky or small and compact. Backpacks can be compressed depending on the composition and position of the load.

Failure to recalibrate decisions to new affordances can lead to erroneous decisions. Backpack wearers typically compensate for the added burden by tilting their bodies away from the load, (Bloom & Woodhull-McNeal, 1987; Goh, Thambyah, & Bose, 1998; Vacheron, Poumarat, Chandezon, & Vanneuville, 1999), taking slower and shorter steps (Schwebel, Pitts, & Stavrinos, 2009), and having longer periods of double support (Wang, Pascoe, & Weimar, 2001). Several studies suggest that wearing a backpack influences adults' perception of slant and distance (Bhalla & Proffitt, 1999; Proffitt, Stefanucci, Banton, & Epstein, 2003) and is linked to unsafe road crossing behaviors (Schwebel et al., 2009).

Navigating through openings with altered body dimensions

Trying to navigate through openings with altered body dimensions, such as a backpack, poses an interesting problem for motor control. According to Wagman and Taylor (2005) individuals must treat changes in body dimensions, such as wearing an object, as an extension of the body. They must recognize that the dimensions of the objects may constrain which openings they can get through. Recalibration to changes in affordances prevents injury, frustration, and property damage. To safely pass, the combined dimensions must be smaller than the aperture. Furthermore, individuals' strength, flexibility,

and coordination, which are important determinants of affordances (Day, Wagman, & Smith, 2015), may also change with altered body dimensions.

Many, but not all, of the studies that examined how adults cope with increased body dimensions reveal that adults can quickly recalibrate their decisions to new affordances and make accurate decisions. In one study, adults wore a glove that increased the width of their hand by approximately 10% as they attempted to fit their hand through different sized openings (Ishak et al., 2008). Although they sometimes erred and attempted openings that were 0.50 to 1.00 cm too small, their actions shifted according to their new hand dimensions. College students whose abdomens were increased by 15 cm via a "pregnancy pack" also erred by a small margin of only 2 cm (Franchak & Adolph, 2014b). Another study, in which adults judged which barriers they could walk under while wearing blocks on their feet or a helmet, found that adults closely matched barrier heights to their new height (Stefanucci, & Geuss, 2010). However, firemen asked to estimate the smallest apertures they could walk through and under while wearing bulky firefighting gear overestimated the apertures they could walk through by 4 cm and underestimated barriers they could go under by 15 cm (Petrucci, Horn, Rosengren, & Hsiao-Wecksler, 2016).

Other experiments with hand-held objects and wheelchairs also show mixed findings regarding affordance perception. For instance, several experiments with adults holding T-shaped bars found that their decisions about whether they could fit through doorways were sensitive to affordances (Higuchi et al., 2006; Wagman & Malek, 2007; Wagman & Taylor, 2005). Furthermore, adults hit the sides of the apparatus when they walked through apertures holding a horizontal bar and wearing shutter goggles (Muroi & Higuchi, 2017). Two of the studies that examined adults' affordance perception for wheelchair passage showed that novice wheelchair users were likely to indicate they could fit through doorways that were 8 cm too small for both rolling through (Yasuda, Wagman, & Higuchi, 2014) and under (Stoffregen, Yang, Giveans, Flanagan, & Bardy, 2009). Additionally, adults most frequently collided with the apparatus while in a wheelchair compared to other conditions (Higuchi et al., 2006). However, Shaw, Flascher, and Kadar (1995) found that adults correctly choose apertures that were 1.22 times the width of the wheelchair as the smallest ones they could roll through.

Previous research shows that adults use a variety of strategies to account for increased body dimensions. For example, adults increased their shoulder rotation when they walked through apertures while wearing large shell-style shoulder pads used in American football (Higuchi et al., 2011). Another study showed that adults turned sideways for apertures that were 1.3 times the size of a wide, hand-held tray rather than their own body width (Hackney, Cinelli, & Frank, 2014). Additionally, they took slower, more deliberate steps as they approached apertures while holding the tray. When navigating in a wheelchair, adults move their head and torso (Stoffregen et al., 2009) presumably to attain information about the size of the wheelchair relative to the aperture.

Experience and navigating through openings with altered body dimensions

Several studies show conflicting results regarding the role of experience in fitting through apertures with altered body dimensions. Specifically, adults' estimates improved

by 10 cm compared to their initial estimates after they received practice walking through doorways while wearing a pregnancy pack (Franchak & Adolph, 2014b). However all experience is not equal, the type of experience seems to matter. For example, only those who had their eyes open and either practiced squeezing through apertures or received verbal feedback about whether they could squeeze through showed improved accuracy from pre- to post-test estimates (Franchak, 2017). In contrast, adults in the same study who squeezed through apertures with their eyes closed or were instructed to compress the backpack itself did not accurately perceive affordances.

Franchak and Somoano (2018) confirmed that, for squeezing through apertures with backpacks, adults recalibrated their judgments more closely to actual affordances when they received verbal and physical feedback about both passable and impassable openings. Receiving feedback about only impossible or only passable apertures was not sufficient for adults to hone in on the limits of their abilities. Similarly, adults' estimates for the doorways they could walk through while holding a horizontal bar improved from pre- to post-test only when they received practice with apertures closest to the size of the bar (Yasuda et al., 2014). Moreover, recent research shows that practice with walking through apertures does not provide the same benefit to all adults. It only helped those who had initially overestimated the apertures they could walk through without turning (Du, Barnett, & Wilmut, 2016).

Studies with novice wheelchair users estimating which openings they could fit through while in a wheelchair show mixed findings as well. For instance, after two minutes of self-propelled practice either moving in a wheelchair or rolling under barriers adults made accurate estimates of the lowest barriers they could roll under (Stoffregen et al., 2009; Yu & Stoffregen, 2012). But, adults who were passively wheeled by an experimenter for the same amount of time were off by 10 cm for the lowest barriers they could go under (Yu & Stoffregen, 2012). Likewise, adults given eight days of experience maneuvering themselves in a wheelchair incorrectly estimated they would be able to roll through openings about 8 cm smaller than the wheelchair (Higuchi, Takada, Matsuura, & Imanaka, 2004). Despite receiving direct experience with wheeling through a variety of apertures sizes, adults' estimates did not show improvement (Yasuda et al., 2014). In fact, adults who received only practice trials that were ±3 cm away from the wheelchair's width showed decreased accuracy on their post-test estimates. Thus, the role of experience in aperture affordance perception under conditions of altered body dimensions, especially in a novel skill, remains unclear, despite the variety of rich research studies.

Current study

The primary aim of this study was to examine the role of experience in affordance perception when body dimensions are altered. Specifically, the findings of this study will help clarify how experience affects decisions about navigating apertures. As discussed above, research studies using the aperture paradigm provide evidence, although not overwhelming, that various types of experience can lead to aligning decisions to affordances. Previous affordance research using other tasks provides some evidence that

experience can improve affordance perception (e.g., Jacobs, Michaels, & Runeson, 2000; Mark, Balliet, Craver, Douglas, & Fox, 1990; Wagman, 2012).

Many of the previous aperture studies tested participants using the most common form of independent locomotion, walking, to examine affordances for fitting through apertures. However, we sought to use a skill that was less common and would involve different movements than walking. One reason for doing this, as suggested by Franchak, van der Zalm, and Adolph (2010), is that walking is highly practiced and experience may not be as beneficial as compared to a novel activity. Indeed, they found that motor decisions for walking through apertures differed by only a few centimeters between adults who did and did not receive practice. Thus, we asked adults to low crawl under barriers of different heights. Because low crawling is a skill that adults may not practice on a regular basis, providing them experience may make a larger impact on their decisions. Moreover, asking individuals to low crawl under barriers would also allow us to expand perception-action research to an unstudied locomotor posture.

Low crawling (also called belly, army, and commando crawling), often precedes both hands-and-knees crawling and walking (Adolph, Vereijken, & Denny, 1998). Maturational theorist Arnold Gesell (1949) described young infants' low crawling as "crawling on a groveling abdomen" within his twenty stages before the onset of independent walking. It is also one of the maneuvers taught to military personnel and features in physical fitness tests (U.S. Department of the Army, 2008). To low crawl, one lays prone with the body touching the ground. Forward movement is generated by pulling the body forward with the arms and pushing with the legs, while the stomach maintains contact with the ground. This position results in the body having a low silhouette against the ground (U.S. Department of the Army, 2008). Low crawling involves a different viewpoint, coordination of different muscle groups, and maintaining a different position than walking. For instance, being able to do more sit-ups and push-ups enables one to low crawl faster (Frykman, Harman, & Pandorf, 2000) but that is unlikely to be true of walking.

Participants' task was to choose the largest backpack, from among five commercially available ones, they thought they could wear to successfully low crawl under barriers of different heights. The backpacks were similar in weight, but varied in thickness from 10 to 30 cm. In much of the previous work, changing adult's body dimensions was accomplished by giving everyone an identical piece of equipment. For instance, in Ishak et al. (2008), adults wore the same 1-cm glove on their pinky finger and in Yasuda et al. (2014) all participants were given the same 66-cm wheelchair. They were not given options because past work was interested in how adults reacted to their new body dimensions. Practical considerations, such as study length and laboratory space, may also limit presenting a variety of choices. Furthermore, using the same apparatus maintains experimental consistency across participants and researchers. However, doing so is essentially using a one-size-fits all approach that ignores the potential for disproportional changes an item may place on different people. For example, a backpack that is 20 cm thick represents a 100% increase in sagittal width for someone with a 20 cm sagittal width but represents only a 50% increase for someone with a sagittal width of 40 cm. Thus, asking adults to choose their own backpack would allow them to tailor their choices.

To examine how experience relates to perception of affordances, we assigned participants to either the Pre/Post-choice (PP) experience condition, Feedback condition, or No Experience condition. Participants in the PP condition low crawled under barriers immediately before picking a backpack and then low crawled wearing the backpack under the same barrier. Thus, they received both pre- and post-choice experience. However, participants in the Feedback condition received low-crawling experience only after they made the backpack choice by low crawling with the backpack on their back. Participants in the No Experience condition made their backpack choices without receiving any crawling experience. Adults in both the PP and Feedback conditions could use haptic, proprioceptive, and visual information as they low crawled under the barrier to inform their choices. The difference between the conditions is the type of experience they received. Participants in the No Experience condition could use visual information as the barriers and backpacks were not hidden from view.

According to Franchak and Adolph (2014a), affordances should be considered as probabilistic in nature due to variability in motor performance. They suggest that assessing an individual's affordance perception requires collection of the individuals' task performance. Therefore, we indexed accuracy based on motor performance rather than on biomechanical models. In contrast to past work, where adults only estimated which openings they could fit through, we checked the accuracy of participants' decisions by having them don their chosen backpack and low crawl under the given barrier. We analyzed whether there were differences between trial outcomes across the conditions. Accordingly, we coded each trial outcome as an erroneous decision if the backpack touched the barrier and a correct decision if it did not.

Consistent with previous research (e.g., Franchak et al., 2010), we collected body dimensions to determine if there was a relationship between body dimensions and backpack choices. Although not empirically tested, it is likely that the widest part of the body protruding in the sagittal plane constrains which barriers adults can fit under. We also noted whether they looked at the backpacks and barriers as a measure of visual exploration and analyzed how this related to their decisions and performance because past research (e.g., Higuchi, Cinelli, & Patla, 2009; Muroi & Higuchi, 2017) shows that visual information is critical for guiding actions adaptively.

Based on past findings, we expected that the different types of low-crawling experience would result in differences between the conditions. We hypothesized that the PP group would choose the smallest backpacks, followed by the Feedback group, and the No experience condition would choose the largest backpacks. Choosing smaller backpacks would imply that the experience of low crawling before choosing a backpack caused participants in the PP condition to adopt a conservative response criterion. In line with previous work, we hypothesized that participants in the PP condition would produce the fewest failures, followed by the Feedback group, and that the No Experience group would have the most failures. Fewer errors in the PP condition than in the other conditions would suggest that low-crawling experience prior to choosing a backpack influenced decision making. Finally, we hypothesized that participants in the PP condition would be least likely to look back at the apparatus, followed by the Feedback condition, and that the No Experience group would be most likely to look

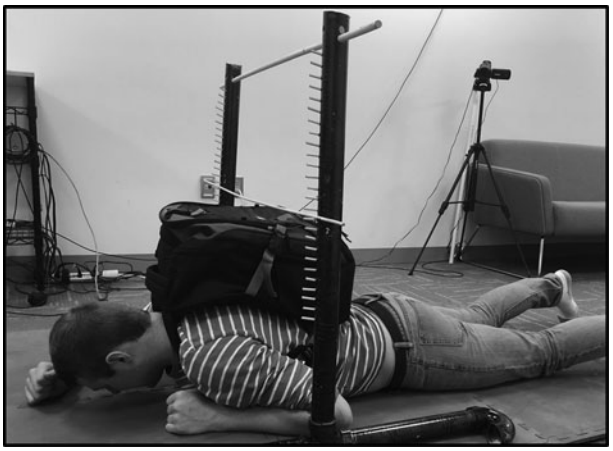

Figure 1. Participant low crawling under a barrier wearing a backpack.

back. The PP would be able to make their decision based on crawling experience rather than having to search for additional visual information.

Method

Participants

Eighty-four undergraduate students (53 females, 31 males; M_{age} = 20.17 years, range = 18.15 to 25.38 years) participated in the study to fulfill either a course requirement or for extra credit in a psychology class. Data from four additional adults were excluded from the analysis due to procedural errors. Participants reported their ethnicity as White ($n = 51$), Asian ($n = 7$), Hispanic ($n = 14$), Black ($n = 2$), other ($n = 6$) and four chose not to indicate their ethnicity. All students had normal or corrected-to-normal vision. They were naïve to the hypotheses of the study, but were informed to wear clothing suitable for exercise when they signed up to participate. Each person participated in either the Pre/Post experience (PP), Feedback, or No Experience condition. All participants provided both verbal and written consent prior to the start of the study. The protocol and consent form were approved by the Ramapo College IRB. Participants in the No Experience condition were run approximately one year after the participants in the other conditions.

Equipment

As shown in Figure 1, we constructed a height-adjustable apparatus using two PVC pipes (89 cm tall x 4.80 cm diameter) and a flat wooden stick (0.64 cm diameter x 122 cm tall) to present participants with barriers of different heights. The height could be adjusted in 2-cm increments (from 32 to 82 cm) by resting the bar on wooden dowels that were embedded into the PVC pipes. The width of the apparatus could be adjusted from 0 to 112 cm by sliding the PVC pipes apart; however, the width of the apparatus remained fixed at approximately 74 cm. Five identical, commercially available backpacks (each 35 cm wide x 50 cm long) were placed strap side down 2.20 m away

Table 1. Participants' mean body dimensions.

	Weight (kg)	Height (cm)	Width (cm)	Depth (cm)
Pre/Post Experience	64.40 (12.14)	168.42 (10.96)	41.22 (3.44)	18.43 (3.11)
Feedback Experience	67.51 (13.20)	169.54 (8.68)	43.29 (3.70)	20.11 (2.93)
No Experience	68.02 (11.55)	161.30 (16.86)	46.87 (21.24)	20.71 (2.40)

Note. *SD*s indicated in parentheses.

from the barrier. The five backpacks were stuffed with lightweight materials so that each one was either 10, 15, 20, 25, or 30 cm thick ($M_{\text{weight}} = 1.17$ kg, $SD = 0.31$). The stuffing was arranged to prevent deformation of the backpacks.

Four video cameras recorded each session. One camera was placed at participants' eye level, facing the backpacks to record their backpack choice. Two additional cameras were placed on either side of the backpacks to capture participants' direction of gaze. Another camera recorded a zoomed-in side view of the body as it passed under the barrier.

Body measurements

The experimenter measured shoulder width, shoulder depth, and height after explaining the study (see Table 1). To ensure precise measurements, an anthropometer was used for all of the measurements, except height. For shoulder width, each arm of the anthropometer was placed at the tip of the right and left humerus, the widest point of the shoulders. For depth, one arm of the anthropometer was placed on the scapular spine and the other was placed on the participant's chest, directly horizontal from the scapular spine. Each body dimension was measured twice and the average was used in the study.

Barrier heights

The experimenter used participants' shoulder depth to determine the barrier heights for the session. There was always at least one hypothetically correct backpack that participants could wear to successfully low crawl under the barrier. We used the formula: Backpack Height + Shoulder Depth + 6 cm buffer. A buffer of 6 cm was included because pilot testing revealed that participants' bodies bobbed up and down as they low crawled. This formula resulted in barrier heights that were 16, 21, 26, 31, and 36 cm larger that participants' shoulder depth. They were presented with each height once from among one of four possible orders. The first and last trials were always at 70 cm because it was relatively easy to low crawl under and is similar to barrier heights used in previous research describing how to low crawl (Frykman et al., 2000; Pandorf et al., 2003). Participants received a total of seven trials.

Procedure

Before the start of the trials, an experimenter demonstrated how moving the wooden stick changed the height of the apparatus. The experimenter then demonstrated how to low crawl under a 70 cm barrier. Next, only participants in the Pre/Post (PP) and Feedback conditions low crawled under the same barrier and the experimenter verbally corrected their form, if necessary. They were all able to successfully low crawl under the 70 cm barrier with their stomach touching the ground. The experimenter pointed at the backpacks

and told participants, "Choose the largest backpack that you think you can wear on your back and low crawl under the barrier without the bag touching the barrier."

Between trials, all participants faced away from the apparatus while the experimenter adjusted the height. Once, the experimenter said "Go," they turned around to face the apparatus. For each trial, after participants in the PP group turned around, they first low crawled under the given barrier, made their backpack choice, put on the backpack, and low crawled back under the barrier to the other side. However, after participants in the Feedback condition turned to face the apparatus, they first put on the largest backpack they thought they could successfully low crawl with given the current barrier height. Then, they low crawled under the barrier while wearing the backpack. After participants in these conditions low crawled with the backpack, they removed it and the experimenter returned the backpack to its original location. Once participants in the No Experience condition turned around, they pointed to their backpack choice for each barrier height. Once all of the trials were completed, they also put on their backpack choice for each barrier and then low crawled under the barrier to check for accuracy. Participants were not told that they could state that none of the backpacks would fit. Each experimental session lasted approximately 30 minutes.

Coding scheme

All of the sessions were coded from video using Datavyu (www.datavyu.org), a computer program that allows coders to indicate timing and occurrence of events. We coded backpack choice as the backpack that participants decided was the largest one they could wear to low crawl under the given barrier. If participants indicated that none of the backpacks would fit, their backpack choice was coded as a 0. Trial outcome was coded when participants low crawled under a barrier wearing a backpack. It was either coded as a success (crawled without backpack touching barrier), failure (backpack touched or knocked down barrier), or refusal (participant said that all of the backpacks were too large or they could not fit with any of backpacks). We scored participants' visual exploration for each trial from video as a "yes" if the participant looked back and forth at the barrier and backpacks at least once prior to picking a backpack.

Data analysis

Backpack choices

Trials at the 70 cm barrier height were not included in any of the analyses. We first examined whether there were differences between experiential conditions by conducting a repeated-measures ANOVA on the backpack size chosen at each barrier height with condition as the between-subjects variable. All significant main effects and interactions were followed up by post-hoc Tukey's HSD tests. Statistical significance was set at $p < .05$ level. We also correlated mean backpack height chosen and barrier height as an additional analysis of whether participants scaled their backpack choices to the barrier height. Additionally, we correlated body dimensions with mean backpack chosen for each condition. The extent to which participants' body dimensions correlated to the size

of the backpack chosen indicated whether participants took their body dimensions into account.

Next, we examined whether participants matched their backpack choice to a hypothetically correct one by calculating a matching score for each trial. For example, if the hypothetically correct bag for the given barrier was 15 cm and a participant chose the 20 cm bag, they were given a matching score of +1 for the trial; if a participant chose the 10 cm bag then their matching score for that trial was −1, etc. Positive numbers indicate liberal choices and negative numbers indicate conservative choices.

We also performed separate chi-square tests on the percentage of trials that were categorized as liberal, matching, or conservative. To determine which experimental conditions were different from each other, we conducted post-hoc analysis on the adjusted residuals (after Beasley & Schumacker, 1995). We used a Bonferonni corrected alpha level of .05/6 = .008, which converts to a two-tailed critical value of z = 2.65. Therefore, we considered adjusted residuals with absolute values larger than 2.65 significant. Significant residuals indicated which combinations of condition and category type tended to occur more or less than expected by chance.

Failure rates

In the next set of analyses we examined participants' failure rates to determine whether participants in one condition versus another were more likely to make accurate decisions. Lower failure rates would indicate higher accuracy. We performed chi-square tests on the percentage of participants that failed and the percentage of failure trials between conditions. We used the same post-hoc analysis method as above to determine which experimental conditions were different from each other. Significant residuals indicated which condition had more or less failures than expected by chance.

Looking back

In the final set of analyses we determined whether there were differences between conditions in visual exploration by analyzing the percent of trials that participants spent looking back and forth at the backpacks and barrier using a chi-square analysis.

Results

Backpack choices

Figure 2 shows participants' decisions by the proportion of trials in which participants either picked a particular backpack or refused. Instead of maintaining a rigid strategy of choosing the smallest 10-cm backpack, participants scaled their backpack choices to the height of the barrier. Although all participants were given the same instructions to wear the largest backpack, only participants in the PP group condition ($n = 16$) indicated at least once that none of the backpacks would fit. All three groups tended to choose larger backpacks for higher barriers and smaller backpacks for lower barriers. A 5(Barrier Height) x 3(Condition) repeated measures ANOVA on the size of the backpack chosen showed main effects for barrier height, $F(4,312) = 190.32$, $p < .001$, partial

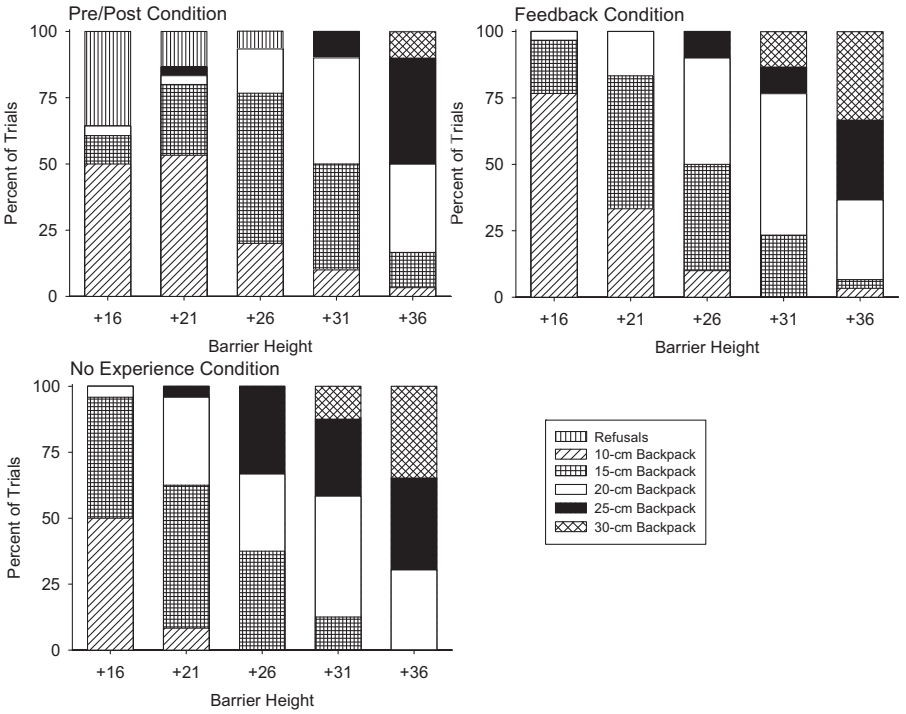

Figure 2. Percentage of trials participants that picked each backpack or refused by each barrier height for each condition.

η^2 =.71 and experimental condition, $F(2,78) = 14.93$, $p < .001$, partial $\eta^2 = .28$. The interaction between barrier height and condition was not significant, $F(4,312) = 0.77$, $p > .05$. A significant linear trend ($F(1,78) = 598.69$, $p < .001$, partial η^2 =.89) for barrier height confirmed that backpack size increased with barrier height. Tukey's HSD post-hoc test showed that the PP group picked significantly smaller bags than the other two groups.

Significant correlations between backpack size chosen and barrier height for each trial provided additional evidence that participants picked larger backpacks for higher barriers, ($r(148) = .75$, $p < .001$ for the PP condition, $r(148) = .75$, $p < .001$ for the Feedback condition, and $r(117) = .75$, $p < .001$ for the No Experience condition). Using a Bonferonni corrected alpha of .05/6 = .008, shoulder depth and shoulder width significantly correlated with mean backpack chosen for the PP and Feedback conditions. The correlation between depth and backpack size chosen was $r(28) = .54$, $p = .002$ for the PP condition and $r(28) = .60$, $p = .011$ for the Feedback condition. The correlation between width and backpack size chosen was $r(28) = .47$, $p = .008$ for the PP condition and $r(28) = .47$, $p = .009$ for the Feedback condition. Neither of the variables significantly correlated with mean backpack chosen for the No Experience condition.

A one-way ANOVA on participants' mean matching score was significant, $F(2,83) = 16.37$, $p < .001$. Tukey's post-hoc HSD test revealed that the PP group ($M_{score} = -1.05$) was more conservative than both the Feedback and No Experience groups, (M_{score} = –.48 and –.13 for Feedback and No Experience group, respectively). In other words, participants in the PP condition were likely to choose backpacks that were either

Table 2. Categories of participants' backpack choices.

	Liberal	Matching	Conservative
Pre/Post Experience	4.0%*	22.3%*	73.7%*
Feedback Experience	12.7%	45.3%	42.0%
No Experience	26.9%*	39.5%	33.6%*

*Significant at adjusted alpha level of .05

one or two sizes smaller than the hypothetically correct backpack, but participants in the other conditions were likely to choose either the hypothetically correct backpack or one size smaller.

Table 2 shows the percent of participants' backpack choices for each trial categorized as either liberal, conservative, or matching. All three χ^2 tests for each category were significant, all ps $< .001$. The adjusted residuals indicated that the No Experience condition resulted in a significantly higher percent of liberal trials and a significantly lower percent of conservative trials compared to the other conditions. In contrast, the PP condition resulted in a significantly lower percent of liberal and matching trials, but a significantly higher percent of conservative trials.

Failure rates

A chi-square analysis on the percent of participants that failed at least once in each condition showed a trend toward significance, $\chi^2(2, N = 84) = 5.87$, $p < .053$. In the PP condition, 73.3% of participants, 93.3% in the Feedback condition, and 91.6% of the participants in the No Experience failed at least once. However, a chi-square on the percent of failure trials revealed a significant effect, $\chi^2(2, N = 417) = 11.19$, $p < .004$. The adjusted residuals indicated that a significantly higher percentage of failure trials occurred in No Experience condition (50.4%) than in the PP condition (30.4%) and Feedback conditions (38.0%).

Participants' failures in the PP and Feedback conditions were concentrated on the lowest +16-cm barrier, suggesting that they had the most difficulty crawling under it. Over one-third (35.6%) of the PP conditions' failures and 42.1% of the Feedback conditions' failures were on the +16-cm barrier. However, most of the failures (33.3%) in the No Experience condition occurred on the +21-cm barrier. Participants' failures in the PP and Feedback conditions were also most frequent when they wore the smallest, 10-cm backpack, presumably because they were crawling under the lowest barriers. Almost half of participants' failures occurred when they wore the 10-cm backpack in the PP (40.0%) and Feedback (42.1%) conditions. In contrast, participants in the No Experience condition failed 36.7% of the time when they wore the 15-cm backpack.

Looking back

Participants were free to turn their heads to look back and forth at the barrier and backpacks when deciding which backpack to wear. Overall, participants looked back on 59.4% of the trials at least once when making their decisions. A chi-square analysis revealed a trend for the percent of trials that participants in each condition looked back, $\chi^2(2, N = 374) = 5.56$, $p < .06$, (60% for PP condition; 51.8% for Feedback

condition; 67.4% for No Experience condition.) There was no difference across the barrier heights (approximately 20% for each barrier); they were just as likely to look back for high versus low barriers. However, when they looked back they were more likely to pick a smaller versus larger backpack. They choose the 10 cm backpack on 18.3% of lookback trials, the 15 cm backpack on 31.1% of lookback trials, and the 20 cm backpack on 27.9% of lookback trials. They picked either the 25 cm or 30 cm backpack, or refused on the remaining 22.7% of trials.

Participants who looked back succeeded on 30.6% of trials, but participants also succeeded on 20.8% of trials when they did not look back. Looking back did not influence participants' likelihood of failing; they failed on 19.4% of trials when they looked back and 14.8% of trials when they did not look back. However, participants seemed to use visual information to guide their refusal decisions as they refused after looking back on 62.5% of refusal trials.

Discussion

This study examined how different experience conditions related to adults' backpack choices, failure rates, and looking behavior. Some participants low crawled under a barrier just prior to choosing the largest backpack they thought would fit under it and others low crawled after picking a backpack. The rest of the participants chose a backpack without first low crawling. We asked adults to low crawl, not walk, in order to add information about a different locomotor posture to the perception-action and affordance literatures. The findings supported our hypotheses that participants in the Pre/Post condition would choose smaller backpacks and produce fewer failures. In this discussion we highlight some of our findings and discuss the implications.

Backpack choices

All participants were given the same instructions to pick the largest backpack to safely low crawl under the barrier. None of the participants used the strategy of wearing the smallest backpack for every barrier, although they were free to do so. Instead, they seemed to keep the instructions in mind as they made their choices. Across trials and conditions, we found that participants used all five of the backpacks and sometimes refused to pick a backpack. More important, they sought to align the backpack height with the barrier height, meaning they picked thicker backpacks for higher barriers. They always chose the largest, 30-cm backpack for the baseline 70-cm trials and frequently chose the smallest 10 cm backpack for the lowest barriers. This shows that participants maintained sensitivity to changes in affordances even when they were the ones to decide how much to alter their body dimensions. Of course, this also reflects adherence to the directions they were given. Nonetheless, they approached the task by scaling their selections according to affordances. Although previous research altered body dimensions in other ways, we believe these results are consistent with those studies. For instance, Wagman and Taylor (2005) asked adults to estimate whether T-shaped poles ranging in width from 50–140 cm would fit through a 90-cm doorway. Participants' likelihood of saying that the pole would fit gradually increased with larger pole sizes.

Participants' decisions in the current study probably entailed not only the bag and barrier heights, but also information about expectations of their own bodies and low-crawling ability. Though there were many aspects to consider, participants took only a few seconds to decide on each trial. This could be because they thought all of the necessary information was readily available. We were particularly interested in whether perceptual-motor information such as optic flow and proprioception generated by first going under the barrier translated into differences between the experimental groups. Similar to past studies in which experience was manipulated, there were differences in several dependent measures between conditions in the current study (e.g., Franchak et al., 2010; Franchak & Adolph, 2014b; Yasuda et al., 2014). Specifically, participants in the No Experience condition were more likely to pick larger backpacks and hit the barrier with the backpack, but less likely to refuse compared to participants in the Pre/Post and Feedback conditions.

Although a few other aperture-navigation studies suggest that experience does not change affordance perception (e.g., Petrucci et al., 2016; Yasuda et al., 2014), methodological differences provide explanations for the discrepancy with our findings. For instance, one possibility offered for the lack of improvement in Yasuda et al. (2014) is that novice wheelchair users' pre-practice estimates for aperture passability were at ceiling, thus there was little room for improvement. This is in contrast to estimates given by our No Experience group. Additionally, Petrucci et al. (2016) did not compare their findings to non-firefighter adults, whose estimates may be significantly different from those of the experienced firefighters they tested.

We concluded that the Pre/Post group was more conservative than the other groups because they chose smaller backpacks, were more likely to refuse, and a higher percentage of their trials were categorized as conservative. The data support our hypotheses. One possible explanation for the pattern of responses might be an artifact of the between-subjects design such that larger participants serendipitously ended up in the Pre/Post group and smaller participants were in the No Experience group. Previous research shows affordance perception differences based on absolute aperture size in large versus small and tall versus short participants (e.g., Warren & Whang, 1987; Wagman & Malek, 2008). Smaller/shorter participants tended to try openings that taller/larger participants refused. If participants in the Pre/Post group were larger, then their conservative choices could be explained by their larger body size rather than as an effect of practice. However, there was no statistically significant difference between the conditions for any of the body dimensions we collected. In fact, the significant positive correlations between backpack size and body dimensions showed that wider participants tended to pick larger, not smaller, backpacks. Experimenter bias or procedural error is a possible for the lack of refusals by the Feedback and No Experience groups. But, they received similar procedures (other than the experimental manipulation) and had similar equipment setups. A review of the videos did not reveal any obvious differences and participants were not aware of the experimental manipulation ahead of time.

Choosing smaller backpacks, like participants in the Pre/Post group, functions to leave a margin of safety between the backpack and the barrier. This safety margin may allow for successful passage despite erroneous decisions or fluctuations in locomotion.

Other aperture studies also found that participants leave a safety margin when walking through doorways (Higuchi et al., 2004). One possible factor for conservative responses is the penalty for error in the current study. If participants hit the barrier, the experimenter told them to stop so he could retrieve the stick and participants stood up and replaced the backpack. Sometimes the stick landed on the participant and in rare cases it snapped in half and was replaced by an identical one. The penalty may have been enough to deter participants in the Pre/Post group from engaging in risky behavior. Indeed, even infants seem to take into account the penalty for an erroneous decision in locomotor tasks. For instance, experienced walking and crawling infants behave cautiously when presented with high-penalty downhill slopes, but the same infants relentlessly attempt to ascend low-penalty uphill slopes (Adolph, 1997). Modifying the cost or benefit associated with participants' decisions such as losing a reward or being told that the backpack held a fragile or indestructible object could shift adults' response criteria to be more or less conservative in a future study.

Van der Meer (1997) suggested that a large safety margin was a way to compensate for a lack of motor control and certainty of motion because children with cerebral palsy left themselves a large safety margin when walking under barriers. According to this idea, people should become less conservative as they gain coordination via experience with a particular skill. In contrast, experience in our task shifted participants' response criterion to be conservative. One possible reason that the Pre/Post group was more conservative is that the amount of practice in our study (only one trial before making a decision) was too little to cause a decrease in the safety margin. Participants' might decrease their safety margin if they were more confident through extensive practice with low crawling. Many of the participants spontaneously commented during the debriefing that they could do better with more practice.

There are several possible strategies we could adapt to use with the current paradigm. For instance, Franchak and Somoano (2018) found that participants who practiced several times by squeezing through small openings initially gave conservative estimates that become less conservative with more practice. To establish whether there are changes in the safety margin, future research could give participants extensive practice low crawling (e.g., 1–4 trials low crawling under each barrier with each backpack) and measure their decision making over time to see if and when their response criterion becomes less conservative. If the findings show that participants with more trials and extensive practice leave a larger safety margin, then it would suggest that experience functions to decrease rather than increase our safety margin.

On the other hand, longitudinal research with infants crawling down slopes shows that they become more, not less, cautious over weeks of crawling (Adolph, 1997), which may be the case with the skill of low crawling as well. Indeed, participants in both the Feedback and No Experience conditions seemed to adopt this strategy and permitted themselves less of a margin of safety, much like infants crawling down slopes. Another possibility for the current study findings is that the low level of motor control that children with cerebral palsy experience is very different from what participants in this study experienced. All participants could low crawl and none of them struggled to do so; thus, the safety margins are similar across the conditions.

Failure rates

Overall, more than a third of the trials resulted in failures. One possible reason for this may be that participants did not see the combined height of the backpack and their body once it was on their backs. Additionally, it is unclear whether the failure rate is significantly higher compared to past research because most studies did not report error rates and many studies collect judgments not actual performances. A few studies report lower error rates than the current study for walking through apertures and under barriers (Franchak, Celano, & Adolph, 2012; van der Meer, 1997; Wilmut & Barnett, 2010). The higher error rate in the current study may reflect a combination of the greater complexity of the task and less familiarity with the action. In other words, participants failed more often overall because it was simply more difficult than previous tasks. The findings suggest that one way to lower rate of failures in a future study would be to give participants more experience (see also Franchak, 2017), such as low crawling with each backpack under a variety of barriers.

As hypothesized, the rate of failures was higher for the Feedback and No Experience conditions compared to the PP condition. It seems likely that the higher failure rates was linked to their tendency to pick larger backpacks than the PP group. Picking a larger backpack leaves less room for error due to a smaller safety margin. Other research with climbing has found that those with higher anxiety expect to and do perform worse than those with lower anxiety (Pijpers, Oudejans, Bakker, & Beek, 2006). However, no one in either group commented that the action was strange or uncomfortable for them. In fact, their mood was positive during the session and they seemed genuinely interested in the task. Another, less plausible, explanation for the difference is that the PP group were better at low crawling than the Feedback and No Experience group. This seems doubtful because they were all drawn from the population of undergraduate students enrolled in psychology courses.

Reasons for differences between conditions

There were clear differences between the experimental groups, but what did the Pre/Post group gain by first crawling under the barrier? We propose that low-crawling practice provided immediate proprioceptive information on which the Pre/Post group could base their judgments that the Feedback and No Experience groups were missing. They could glean information about the relative height of the barrier and feedback on the fit of their body under the barrier. In fact, participants in the Pre/Post condition looked up at the barrier on 17% of trials as they went under it. During this time they could see how much space was between their back and the barrier. An eye tracker could be used in a future study to better capture direction of gaze and fixations to determine which areas of the environment participants sought to gather information about. When making their decision, they may have remembered themselves crawling under the barrier. Some of the participants even said that they tried to picture themselves going under the barrier as they made their decisions, but it is unknown whether it was helpful from trial to trial.

Beyond geometric properties, participants in the Pre/Post condition most likely also generated dynamic information about the task. Dynamic aspects of action include

coordination, strength, and flexibility (Day et al., 2015), which can be quantified but are not readily available by simply looking. The way to gain this type of information is to perform the action oneself. Specifically, participants could feel the amount of postural sway inherent in low crawling, how close they could get their body to the ground, whether they would be able to balance themselves, how to coordinate their limbs, etc. All of these facets are important aspects of guiding movements adaptively (Adolph, 1997). Cole, Chan, Vereijken, and Adolph (2013) suggested that some actions may be easier to predict because they are constrained primarily by geometric properties, but other actions may be too complex to predict without experience because they are constrained by dynamic factors. Moreover, vision is not informative once participants put on the backpack because they can no longer see it. It is possible that low crawling with a backpack is too complex to accurately predict without experience because of the numerous dynamic aspects and that is why participants in the Feedback and No Experience conditions made poorer decisions than participants in the Pre/Post condition.

The similarity between the Feedback and No Experience conditions sheds further light on the mechanism of dynamic experience. In contrast to our hypotheses, there was little difference between these two conditions on almost every dependent measure. In fact, participants in the Feedback condition were just as likely to look back at the bags and barrier, although they had just crawled under one with a backpack. This behavior suggests that participants in the Feedback condition were searching for information that was not provided by low crawling on a previous trial. Possibly, they ignored or dismissed the previous trial because it was for a different barrier height than the one they were currently facing and they were perceiving affordances on-line. But, participants in the Pre/Post group crawled under the target barrier immediately before making their decisions. This is evidence that closely timed and relevant dynamic experience is critical for affordance perception because there was no difference between Feedback and No Experience conditions. Relying on information in-the-moment rather than prior information is more likely to lead to adaptive decisions.

Many past studies suggest the above sources of information as useful for detecting other types of affordances. For instance, adults who felt themselves squeezing through both possible and impossible doorways made more accurate estimates than those who did not (Franchak et al., 2010; Franchak & Somoano, 2018; Franchak & Somoano, 2018). Similarly, adults who freely moved their head and torso as they estimated the lowest barrier they could traverse in a wheelchair were more accurate than those who could not (Yu, Bardy, & Stoffregen, 2010). Additionally, adults who were asked to practice leaping made more accurate predictions about the maximum distance they could leap and step (Day et al., 2015) than adults who did not practice leaping. In fact, visual information by itself has been shown to be useful for estimating affordances for others, even if viewing an action that is different from the target action (Ramenzoni, Davis, Riley, & Shockley, 2010). Unfortunately, the current study was not designed to tease apart which specific type of information generated by pre-choice practice was most useful in affordance perception, although a future study certainly could. Nonetheless, the findings suggest that when the information is available, people use it.

Conclusion

This study used a less-familiar locomotor posture, low crawling under barriers with altered body dimensions, to examine whether experience influences affordance perception. Similar to previous studies, adults' decisions were scaled to changes in the environment. Additionally, the findings shed further light on the role of experience in affordance perception. We conclude that, at least for low crawling under barriers with altered body dimensions, experience can sway decision making. Further research is needed to determine the mechanism of how experience influences affordance perception.

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References

Adolph, K. E. (1997). Learning in the development of infant locomotion. *Monographs of the Society for Research in Child Development*, *62*(3), Serial No. I.

Adolph, K. E., Vereijken, B., & Denny, M. A. (1998). Learning to crawl. *Child Development*, *69*(5), 1299–1312.

Beasley, T. M., & Schumacker, R. E. (1995). Multiple regression approach to analyzing contingency tables: Post hoc and planned comparison procedures. *Journal of Experimental Education*, *64*(1), 79–93. doi:10.1080/00220973.1995.9943797

Bhalla, M., & Proffitt, D. R. (1999). Visual–motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance*, *25*(4), 1076–1096. doi:10.1037/0096-1523.25.4.1076

Bloom, D., & Woodhull-McNeal, A. P. (1987). Postural adjustments while standing with two types of loaded backpacks. *Ergonomics*, *30*(10), 1425–1430. doi:10.1080/00140138708966036

Cole, W. G., Chan, G. L. Y., Vereijken, B., & Adolph, K. E. (2013). Perceiving affordances for different motor skills. *Experimental Brain Research*, *225*(3), 309–319. doi:10.1007/s00221-012-3328-9

Day, B. M., Wagman, J. B., & Smith, P. J. K. (2015). Perception of maximum stepping and leaping distance: Stepping affordances as a special case of leaping affordances. *Acta Psychologica*, *158*, 26–35. doi:10.1016/j.actpsy.2015.03.010

Du, W., Barnett, A., & Wilmut, K. (2016). The role of movement variability and action experience in the perceptual judgment of passability. *Journal of Motor Learning & Development*, *4*, 307–323. doi:10.1123/jmld.2015-0047

Franchak, J. M. (2017). Exploratory behaviors and recalibration: What processes are shared between functionally similar affordances? *Attention, Perception, & Psychophysics*, *79*(6), 1816–1829. doi:10.3758/s13414-017-1339-0

Franchak, J. M., & Adolph, K. E. (2012). What infants know and what they do: Perceiving possibilities for walking through openings. *Developmental Psychology*, *48*(5), 1254–1261. doi: 10.1037/a0027530

Franchak, J. M., & Adolph, K. (2014a). Affordances as probabilistic functions: Implications for development, perception, and decisions for action. *Ecological Psychology*, *26*(1–2), 109–124. doi:10.1080/10407413.2014.874923

Franchak, J. M., & Adolph, K. (2014b). Gut estimates: Pregnant women adapt to changing possibilities for squeezing through doorways. *Attention, Perception, & Psychophysics*, *76*, 460–472. doi:10.3758/s13414-013-0578-y

Franchak, J. M., Celano, E. C., & Adolph, K. E. (2012). Perception of passage through openings depends on the size of the body in motion. *Experimental Brain Research*, *223*(2), 301–310. doi: 10.1007/s00221-012-3261-y

Franchak, J. M., & Somoano, F. (2018). Rate of recalibration to changing affordances for squeezing through doorways reveals the role of feedback. *Experimental Brain Research*, *236*(6), 1699–1711. doi:10.1007//s00221-018-5252-0

Franchak, J. M., van der Zalm, D. J., & Adolph, K. E. (2010). Learning by doing: Action performance facilitates affordance perception. *Vision Research*, *50*(24), 2758–2765. doi:10.1016/j.visres.2010.09.019

Frykman, P. N., Harman, E. A., & Pandorf, C. E. (2000). Correlates of obstacles course performance among female soldiers carrying two different loads. (Report No. ADA394945) Natick, MA: U.S. Army Research Institute of Environmental Medicine.

Gesell, A. (1949). Human infancy and the ontogenesis of behavior. *American Scientist*, *37*(4), 529–553.

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

Goh, J. H., Thambyah, A., & Bose, K. (1998). Effects of varying backpack loads on peak forces in the lumbosacral spine during walking. *Clinical Biomechanics*, *13*, S23–S31.

Hackney, A. L., Cinelli, M. E., & Frank, J. S. (2014). Is the critical point for aperture crossing adapted to the person-plus-object system? *Journal of Motor Behavior*, *46*(5), 319–327. doi: 10.1080/00222895.2014.913002

Higuchi, T., Cinelli, M. E., & Patla, A. E. (2009). Gaze behavior during locomotion through apertures: The effect of locomotion forms. *Human Movement Science*, *28*(6), 760–771. doi:10.1016/j.humov.2009.07.012

Higuchi, T., Cinelli, M. E., Greig, M. A., & Patla, A. E. (2006). Locomotion through apertures when wider space for locomotion is necessary: Adaptation to artificially altered bodily states. *Experimental Brain Research*, *175*(1), 50–59. doi:10.1007/s00221-006-0525-4

Higuchi, T., Murai, G., Kijima, A., Seya, Y., Wagman, J. B., & Imanaka, K. (2011). Athletic experience influences shoulder rotations when running through apertures. *Human Movement Science*, *30*(3), 534–549. doi:10.1016/j.humov.2010.08.003

Higuchi, T., Takada, H., Matsuura, Y., & Imanaka, K. (2004). Visual estimation of spatial requirements for locomotion in novice wheelchair users. *Journal of Experimental Psychology. Applied*, *10*(1), 55–66. doi:10.1037/1076-898X.10.1.55

Ishak, S., Adolph, K. E., & Lin, G. C. (2008). Perceiving affordances for fitting through apertures. *Journal of Experimental Psychology: Human Perception and Performance*, *34*, 1501–1514. doi: 10.1037/a0011393

Jacobs, D. M., Michaels, C. F., & Runeson, S. (2000). Learning to perceive the relative mass of colliding balls: The effects of ratio scaling and feedback. *Perception & Psychophysics*, *62*, 1332–1340. doi:10.3758/BF03212135

Konczak, K., Meeuwson, H. J., & Cress, E. M. (1992). Changing affordances in stair climbing: The perception of maximum climbability in young and older adults. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 691–697. doi:10.1037//0096-1523.18.3.691

Mark, L. S., Balliett, J. A., Craver, K. D., Douglas, S. D., & Fox, T. (1990). What an actor must do in order to perceive the affordance for sitting. *Ecological Psychology*, *2*(4), 325–366. doi: 10.1207/s15326969eco0204_2

Muroi, D., & Higuchi, T. (2017). Walking through an aperture with visual information obtained at a distance. *Experimental Brain Research*, *235*(1), 219–230. doi:10.1007/s00221-016-4781-7

Pandorf, C. E., Nindl, B. C., Montain, S. J., Castellani, J. W., Frykman, P. N., Leone, C. D., & Harman, E. A. (2003). Reliability assessment of two military relevant occupational physical performance tests. *Canadian Journal of Applied Physiology*, *28*(1), 27–37. doi:10.1139/h03-003

Petrucci, M. N., Horn, G. P., Rosengren, K. S., & Hsiao-Wecksler, E. T. (2016). Inaccuracy of affordance judgments for firefighters wearing personal protective equipment. *Ecological Psychology*, *28*(2), 108–126. doi:10.1080/10407413.2016.1163987

Pijpers, J. R., Oudejans, R. R. D., Bakker, F. C., & Beek, P. J. (2006). The role of anxiety in perceiving and realizing affordances. *Ecological Psychology*, *18*(3), 131–161. doi:10.1207/s15326969eco1803_1

Proffitt, D. R., Stefanucci, J., Banton, T., & Epstein, W. (2003). The role of effort in perceiving distance. *Psychological Science*, *14*(2), 106–112. doi:10.1111/1467-9280.t01-1-01427

Ramenzoni, V., Davis, T. J., Riley, M. A., & Shockley, K. (2010). Perceiving action boundaries: Learning effects in perceiving maximum jumping-reach affordances. *Attention, Perception, & Psychophysics*, *72*, 1110–1119. doi:10.3758/APP.72.4.1110

Schwebel, D. C., Pitts, D. D., & Stavrinos, D. (2009). The influence of carrying a backpack on college student pedestrian safety. *Accident Analysis & Prevention*, *41*, 352–356. doi:10.1016/j.aap.2009.01.002

Shaw, R., Flascher, O., & Kadar, E. (1995). Dimensionless invariants for intentional systems: Measuring the fit of vehicular activities to environmental layout. In J. Flach, P. Hancock, J. Caird, and K. Vicente (Eds.), *Global perspectives on the ecology of human-machine systems* (pp. 293–357). Mahwah, NJ: Erlbaum.

Stefanucci, J. K., & Geuss, M. N. (2010). Duck! Scaling the height of a horizontal barrier to body height. *Attention, Perception & Psychophysics*, *72*, 1338–1349. doi:10.3758/APP.72.5.1338

Stoffregen, T. A., Yang, C.-M., Giveans, M. R., Flanagan, M., & Bardy, B. G. (2009). Movement in the perception of an affordance for wheelchair locomotion. *Ecological Psychology*, *21*(1), 1–36. doi:10.1080/10407410802626001

U.S. Department of the Army. (2008). *The warrior ethos and soldier combat skills. (Field Manual No. 3-21.75)*. Washington, DC: Author.

Vacheron, J. J., Poumarat, G., Chandezon, R., & Vanneuville, G. (1999). The effects of loads carried on the shoulders. *Military Medicine*, *164*(8), 597–599.

van der Meer, A. H. (1997). Visual guidance of passing under a barrier. *Early Development and Parenting*, *6*, 149–157. doi:10.1002/(SICI)1099-0917(199709/12)6:3/4 < 149::AID-EDP154 > 3.0.CO;2-2

Wagman, J. B. (2012). Perception of maximum reaching height reflects impending changes to reaching ability and improvements transfer to unpracticed reaching tasks. *Experimental Brain Research*, *219*(4), 467–476. doi:10.1007/s00221-012-3104-x

Wagman, J. B., & Malek, E. A. (2007). Perception of whether an object can be carried through an aperture depends on anticipated speed. *Experimental Psychology*, *54*(1), 54–61. doi:10.1027/1618-3169.54.1.54

Wagman, J. B., & Malek, E. A. (2008). Perception of affordances for walking under a barrier from proximal and distal points of observation. *Ecological Psychology*, *20*(1), 65–83. doi:10.1080/10407410701766650

Wagman, J. B., & Taylor, K. R. (2005). Perceiving affordances for aperture crossing for the person-plus-object system. *Ecological Psychology*, *17*(2), 105–130. doi:10.1207/s15326969eco1702_3

Wang, Y. T., Pascoe, D. D., & Weimar, W. (2001). Evaluation of book backpack load during walking. *Ergonomics*, *44*(9), 858–869. doi:10.1080/00140130118572

Warren, W. H., & Whang, S. (1987). Visual guidance of walking through apertures: Body-scaled information for affordances. *Journal of Experimental Psychology: Human Perception & Performance*, *13*(3), 371–383.

Wilmut, K., & Barnett, A. (2010). Locomotor adjustments when navigating through apertures. *Human Movement Science*, *29*(2), 289–298. doi:10.1016/j.humov.2010.01.001

Yasuda, M., Wagman, J., & Higuchi, T. (2014). Can perception of aperture passability be improved immediately after practice in actual passage? Dissociation between walking and wheelchair use. *Experimental Brain Research*, *232*(3), 753–764. doi:10.1007/s00221-013-3785-9

Yu, Y., Bardy, B. G., & Stoffregen, T. A. (2010). Influences of head and torso movement before and during affordance perception. *Journal of Motor Behavior*, *43*(1), 45–54. doi:10.1080/00222895.2010.533213

Yu, Y., & Stoffregen, T. A. (2012). Postural and locomotor contributions to affordance perception. *Journal of Motor Behavior*, *44*(5), 305–311. doi:10.1080/00222895.2012.706659