Geometric, Kinetic-Kinematic, and Intentional Constraints Influence Willingness to Pass Under a Barrier

Jeffrey B. Wagman and Eric A. Malek

Department of Psychology, Illinois State University, IL

Abstract. Completing a goal directed behavior in a safe and efficient manner requires that a perceiver-actor is sensitive to the various constraints on performing that behavior and adjust his or her movements accordingly. When attempting to pass under a barrier, people adjust their ducking behavior based on the likelihood and potential costs of a collision (van der Meer, 1997). In three experiments, we investigated whether participants are sensitive to geometric (standing height), kinetic-kinematic (anticipated movement speed), and intentional (material properties of the barrier) constraints on passing under a barrier even before attempting to perform this behavior. Although Experiment 1 failed to show that anticipated movement speed influenced perception of whether a barrier could be passed under, Experiment 2 found that this factor influences willingness to attempt the behavior. Experiments 3a and 3b found that the material properties of the barrier itself also influence willingness to attempt the behavior. Together, the results highlight the contribution of geometric, kinetic-kinematic, and intentional constraints to perception.

Keywords: perception-action, constraints, intention

Completing a goal directed behavior in a safe and efficient manner requires that that the perceiver-actor is sensitive to the constraints on performing that behavior and adjust (or halt) their behavior accordingly (Gibson, 1979; Turvey, 1992). Such constraints often influence both the likelihood of successfully performing that behavior and the potential costs of a failed attempt (see Proffitt, 2006). Research has shown that perceiver-actors are sensitive to the constraints on performing a given behavior provided by their own geometric properties – anthropometric measurements such as body height, shoulder width, arm length, and leg length. For example, people with wide shoulders are more conservative in reporting whether they would be able to pass through doorways of various widths than people with narrow shoulders (Warren & Whang, 1987), and people with short legs are more conservative in reporting whether they would be able to climb stairs of various riser heights than people with long legs (Warren, 1984). Moreover, when attempting to walk through a doorway, people with wide shoulders rotate their shoulders to a greater degree than people with narrow shoulders (Warren & Whang, 1987; see Higuchi, Cinelli, Grieg, & Patla, 2006), and when attempting to walk under a barrier, taller people begin to duck at a higher barrier height than shorter people (van der Meer, 1997).

Research has also shown that perceiver-actors are sensitive to the constraints on performing a given behavior provided by their kinetic potential – their ability to generate and control the muscular forces required for a given behavior. For example, elderly adults are more conservative than younger adults in reporting whether they would be able to climb stairs of various riser heights (Konczak, Meeuwsen, & Cress, 1992) and, people wearing heavy backpacks perceive slopes to be steeper than people not wearing heavy backpacks (Bhalla & Proffitt, 1999; see Malek & Wagman, 2008; Regia-Corte & Wagman, 2008).

One determinant of a person's ability to generate and control the muscular forces required to perform a particular behavior is the movement speed at which they attempt that behavior. In some cases, increases in movement speed serve to increase the likelihood of successfully performing a given behavior (e.g., catching a fly ball, passing over an obstacle, see Oudejans, Michaels, Bakker, & Dolné, 1996; Turvey, 2004). However, in other cases, increases in movement speed serve to decrease the likelihood of success and/or increase the (potential) costs of a failed attempt (e.g., passing through a doorway or passing under a barrier). This is especially so in human bipedal locomotion where increases in movement speed force a gait transition from walking (a series of pendulum-like steps) to running (a series of spring-like leaps) (see Alexander, 1992; Lee & Farley, 1998) and create additional *kinematic* constraints on performing a given behavior.

Research has shown that perceiver-actors are sensitive to how such increases in movement speed place such constraints on performing a given behavior and adjust their behavior accordingly. For example, people rotate their shoulders to a greater degree when walking through a doorway quickly than when walking through a doorway slowly (Higuchi et al., 2006; Warren & Whang, 1987). Similarly,

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people begin to duck at a higher barrier height when attempting to run underneath a barrier than when attempting to walk underneath that barrier (van der Meer, 1997). Other work has shown that perceiver-actors are sensitive to how increases in movement speed place constraints on performing a given behavior even before that behavior is attempted. For example, people are more conservative in reporting whether they would be able to carry an object through a doorway when they anticipate running through the doorway (while carrying the object) than when they anticipate walking through the doorway (while carrying the object) (Wagman & Malek, 2007).

In three experiments, we investigate whether participants are sensitive to geometric, kinetic-kinematic, and intentional constraints on passing under a barrier before this behavior is attempted. Experiments 1 and 2 investigate whether participants are sensitive to constraints provided by their standing height and movement speed. Experiments 3a and 3b investigate whether participants are additionally sensitive to constraints provided by the material properties of the barrier itself.

Experiment 1

Standing height and movement speed influence the likelihood of successfully passing under a barrier and the potential costs of a failed attempt (i.e., they influence both the likelihood and potential costs of a collision). Moreover, when attempting to perform this behavior, people exhibit sensitivity to such constraints and adjust their (ducking) behavior accordingly. In particular, taller people duck at higher barrier heights than shorter people, and people duck at higher barrier heights when running under a barrier than when walking under a barrier (van der Meer, 1997). Experiment 1 builds on these findings by investigating whether perceiver-actors are sensitive to such constraints before attempting the behavior.

We expect that perceptual reports will be influenced both by the participant's standing height and by their anticipated movement speed. Specifically, we expect that (a) tall participants will be more conservative (i.e., they will report that they could pass under the barrier less often) than short participants, especially at intermediate barrier heights (barrier heights in the range of participant heights), and that (b) participants will be more conservative when they anticipate running under the barrier than when they anticipate walking under the barrier. Moreover, we expect that (c) both tall and short participants will be least confident in their judgments within ranges of barrier heights that contain their respective standing heights.

Method

Participants

Twenty female students from Illinois State University participated in this experiment. Participants were recruited in two height categories – those with standing heights greater than 170.2 cm (5 ft 7 in.), and those with standing heights shorter than 160 cm (5 ft 3 in.). Twelve participants were in the "tall" group (*M* = 174.3 cm, *SD* = 1.8 cm), and eight were in the "short" group (*M* = 157.0 cm, *SD* = 2.3 cm). All participants received extra credit in their psychology courses in exchange for their participation.

Materials and Apparatus

The stimuli used in this experiment consisted of a wooden dowel (100 cm in length and 3 cm in diameter) set horizontally into a frame constructed of PVC pipe such that the height of the dowel could be set at nine different heights ranging from 130 to 198 cm in 8.5 cm increments. A tape measure affixed to the wall was used to measure the participants' standing height. It was not visible to the participant until the end of the experiment.

Procedure

Participants stood 350 cm from the frame supporting the horizontal dowel in a designated area (100 cm wide × 40 cm deep) that was centered with the frame.

On a given trial, the participant viewed the dowel set at a particular height and provided two responses. First, she judged ("yes" or "no") whether she would be able to pass underneath the dowel without ducking her head or bending at her knees or waist. Such restrictions were necessary (a) to ensure that each participant was using the same criteria to make their perceptual reports and (b) to allow for a more direct comparison with the results of van der Meer (1997) who defined the behavioral boundary in terms of the highest bar height at which ducking behavior was initiated.

Second, she provided her confidence in that judgment on a scale of 1 ("not at all confident") to 7 ("extremely confident"). Participants were allowed to view the dowel as long as necessary to provide both responses. After doing so, the participant closed her eyes while the experimenter changed the height of the dowel. The experimenter was not visible to the participant at any point during the experiment.

Participants performed this task in two conditions. In the "walk" condition, she judged whether she would be able to walk underneath the dowel, and in the "run" condition, she judged whether she would be able to run underneath the dowel (in both cases, with the above restrictions). Participants completed both conditions in blocked fashion, and the order of these conditions was counterbalanced across participants. Within each condition, dowel heights were presented three times each, and the order of presentation of dowel heights was randomized. At no point during the experiment did the participant approach the PVC frame or attempt to pass underneath the dowel. Participants kept their shoes on throughout the experiment.

Results and Discussion

Perceptual Judgments

The percentage of trials that received a yes response was calculated at each barrier height for each participant in each condition. We compared the mean percentage of yes (i.e., "passable") responses for each group in each condition in a 2 (task instruction: walk vs. run) × 2 (participant height group: tall vs. short) × 9 (barrier height) analysis of variance (ANOVA). A main effect of barrier height revealed that the percentage of yes responses decreased with decreasing barrier height, $F(8, 144) = 126.60$, $p < .01$, $\eta_p^2 = .88$, and a main effect of participant height group revealed that the percentage of yes responses was greater for short participants (60.2%) than for tall participants (42.4%), $F(1, 18) = 20.83$, $p < .01$, $\eta_p^2 = .54$. An interaction of these variables showed that the difference in percent yes responses between tall and short participants depended on barrier height, $F(8, 144) = 9.62$, $p < .01$, $\eta_p^2 = .35$ (see Figure 1a). Followup *t* tests (with Bonferroni corrections) revealed that differences occurred only at intermediate barrier heights (i.e., barrier heights in the range of participant heights). In particular, such differences occurred at barrier heights of 156 cm, $t(18) = 3.72$, $p < .01$; 164 cm, $t(18) = 4.28$, $p < .001$; and 173 cm, $t(18) = 2.51$, $p < .01$. There were no other significant effects (all *F*s < 1.9).

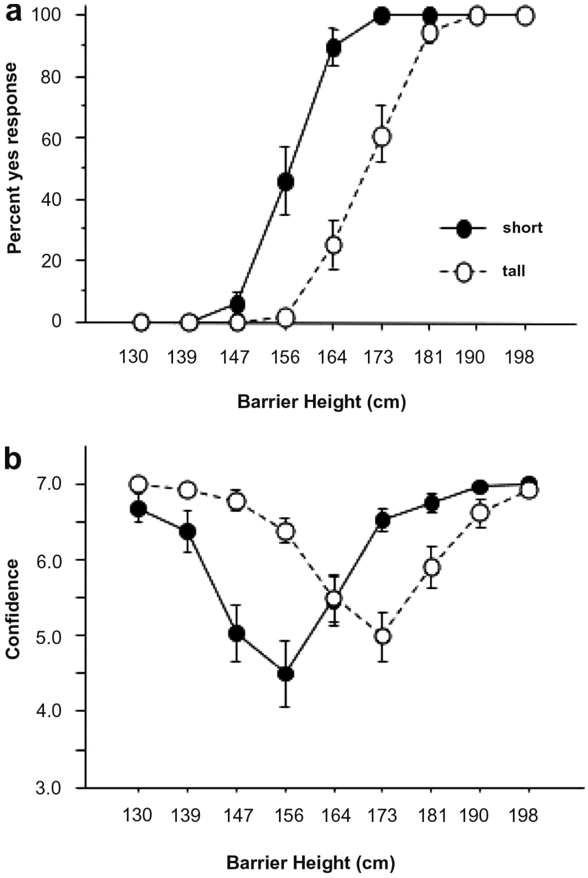

Figure 1. Percentage of "yes" responses as a function of barrier height and standing height in Experiment 1 (a). Mean confidence ratings as a function of barrier height and standing height in Experiment 1 (b). Error bars represent standard error.

The perceptual category boundary for a given participant in a given condition was the lowest barrier height that resulted in a yes response on at least 50% of the trials in that condition (i.e., on at least two of the three trials in that condition) (see Wagman & Malek, 2007; Warren, 1984). A 2 (task instruction: walk vs. run) × 2 (participant height group: tall vs. short) ANOVA revealed that the perceptual category boundary occurred at a higher barrier height for tall participants ($M = 174.3$ cm, $SD = 7.5$ cm) than for short participants ($M = 160.8$ cm, $SD = 6.1$ cm), $F(1, 18) = 18.74$, $p < .01$, $\eta_p^2 = .51$. There were no other significant effects (all other *F*s < 1).

To generate perceptual category boundaries in terms of a ratio of barrier height to participant height, the perceptual boundaries derived for a given participant were divided by that participant's standing height. A 2 (task instruction: walk vs. run) × 2 (participant height group: tall vs. short) ANOVA revealed that there were no significant effects (all *F*s < 1.5). In particular, there was no difference in the rescaled perceptual category boundary for tall participants ($M = 1.00$, $SD = 0.04$) and for short participants ($M = 1.02$, $SD = 0.04$) (see van der Meer, 1997).

Confidence Ratings

We compared the mean confidence ratings for each group in each condition in a 2 (task instruction: walk vs. run) × 2 (participant height group: tall vs. short) × 9 (barrier height) ANOVA. A main effect of barrier height revealed that confidence varied as a function of barrier height, $F(8, 144) = 9.60$ $p < .01$, $\eta_p^2 = .35$. Overall, minimum confidence occurred at intermediate barrier heights and maximum confidence occurred at extreme barrier heights (see Figure 1b). However, an interaction of barrier height and participant height group revealed that the specifics of this pattern differed for tall and short participants, $F(8, 144) = 8.17$, $p < .01$, $\eta_p^2 = .31$.

Inspection of Figure 1b suggests that tall participants exhibit minimum confidence at higher barrier heights than short participants. A *t* test comparing the barrier height at which minimum confidence occurs for tall and short participants confirmed this to be the case (tall: 170.4 cm; short: 156.6 cm; $t(38) = 6.30$, $p < .01$). The ANOVA revealed no other significant effects (all *F*s < 1.15).

Consistent with our hypotheses, tall participants were more conservative than short participants, especially at intermediate barrier heights. Furthermore, both tall and short participants were least confident in their perceptual judgments within ranges of barrier heights that contained their respective standing heights. The perceptual category boundary occurred at a higher barrier height for tall participants than for short participants but at equivalent ratios of barrier height to participant height for each group (tall: 1.00, short: 1.02). Moreover, such boundaries were quite similar to the barrier-height-to-participant-height ratios at which ducking occurs when participants attempt to pass under a barrier (1.05 for both tall and short participants, van der Meer, 1997).

However, contrary to our hypotheses, participants were no more conservative in reporting that they would be able to run under the barrier than in reporting that they would be able to walk under the barrier. This is somewhat inconsistent with the work of van der Meer (1997) who found that people began to duck at a higher barrier height when attempting to run underneath a barrier than when attempting to walk underneath a barrier.

Experiment 2

Experiment 1 failed to show that perceiver-actors are sensitive to how their movement speed influences the likelihood and potential costs of a collision with a barrier. One possibility as to why this was the case is that the dependent measure used in Experiment 1 and in a number of previous studies (i.e., the yes or no response) may have lacked sufficient precision and intentional content to reveal such sensitivity.

Previous studies investigating sensitivity to constraints on performing a particular behavior before that behavior is attempted have typically used one of three dependent measures to do so. A yes or no response as to whether a particular behavior is possible (e.g., Experiment 1, Malek & Wagman, 2008; Wagman & Malek, 2007) explicitly captures the (perceived) ability of the participant to perform that behavior but allows for only limited precision (i.e., the participant has only two response options). Magnitude estimation or magnitude production of a particular environmental property (e.g., perceived geographic slant or perceived linear extent; Bhalla & Proffitt, 1999; Proffitt, Stefanucci, Banton, & Epstein, 2003; Witt, Proffitt, & Epstein, 2004) allows for a great deal of precision but does not explicitly capture the (perceived) ability of the participant to perform a given behavior. Adjustment of an environmental surface to correspond to the limits of a particular behavior (e.g., the steepest slope that would support upright posture, Regia-Corte & Wagman, 2008) seems to do both, but does not explicitly take into account a participant's intention (i.e., a participant may report that they are *able* to perform a particular behavior but be *unwilling* to do so due to the potential costs of a failed attempt).

Experiment 2 attempts to expand both on Experiment 1 and on previous research by developing a sufficiently precise dependent measure that captures both the ability and the intention of the participant to perform a particular behavior. To this end, rather than reporting whether they would be able to pass under a barrier, participants reported *how willing they would be* to do so. To the best of our knowledge, this is the first time that such a dependent measure has been used to investigate sensitivity to constraints on performing a particular behavior. We expect that willingness to pass underneath a barrier will be influenced by both the participant's standing height and their anticipated movement speed. Specifically, we expect that (a) willingness ratings will be higher for short participants than for tall participants, especially at intermediate barrier heights (i.e., barrier heights in the range of participant heights) and (b) willingness ratings will be higher when participants anticipate walking underneath the barrier than when they anticipate running underneath the barrier.

Method

Participants

Participants were recruited from the same population and in the same height categories as in Experiment 1. Fourteen participants were in the "tall" group (M = 176.0 cm, SD = 3.4 cm), and fourteen were in the "short" group (M = 157.7 cm, SD = 6.2 cm).

Materials and Apparatus

The materials and apparatus used in this experiment were the same as in Experiment 1.

Procedure

The procedure for Experiment 2 was the same as in Experiment 1 except that participants reported how willing they would be to attempt to pass underneath the barrier without ducking their head or bending at their knees or waist. Willingness ratings were on a scale of 1 ("absolutely unwilling to do so") to 7 ("absolutely willing to do so").

Results and Discussion

We compared the mean willingness ratings for each group in each condition in a 2 (task instruction: walk vs. run) × 2 (participant height group: tall vs. short) × 9 (barrier height) ANOVA. Due to a violation of the sphericity assumption, a Greenhouse-Geisser correction was applied to all tests involving barrier height. A main effect of participant height group revealed that willingness ratings were higher for short participants (M = 4.9, SD = 2.4) than for tall participants (M = 3.9, SD = 2.4), $F(1, 26) = 19.58$, $p < .01$, $\eta_p^2 = .43$, and a main effect of task instruction revealed that willingness ratings were higher in the walk condition (M = 4.6, SD = 0.90) than in the run condition (M = 4.3, SD = 0.82), $F(1, 26) = 11.16$, $p < .01$, $\eta_p^2 = .30$. A main effect of barrier height revealed that willingness ratings increased as barrier height increased, $F(8, 208) = 227.40$, $p < .01$, $\eta_p^2 = .90$.

There were interactions of participant height group and barrier height, $F(8, 208) = 14.77$, $p < .01$, $\eta_p^2 = .36$ and of task instruction and barrier height, $F(8, 208) = 2.48$, $p < .05$, $\eta_p^2 = .09$, but such interactions were qualified by a three-way interaction of participant height group, task instruction, and barrier height, $F(8, 208) = 2.74$, $p < .05$, $\eta_p^2 = .10$ (see Figure 2). In order to minimize the chance of a Type I error, followup t tests were conducted on the two largest mean differences between ratings in the walk and run conditions for both short and tall participant height groups. For the short participant group, such differences occurred at barrier heights of 147 and 156 cm (differences of 1.4 and 0.3, respectively, see Figure 2a). The difference at 147 cm was significant, $t(13) = 2.42$, $p < .05$, and the difference at 156 cm was not. For the tall participant group, such differences occurred at barrier heights of 173 and 164 cm (differences of 0.7 and 0.5, respectively, see Figure 2b). The difference at 173 cm was significant, $t(13) = 2.93$, $p < .05$, and the difference at 164 cm was not. Thus, the three-way interaction indicates that (a) for short participants, willingness ratings were higher in the walk condition than in the run condition at a barrier height of 147 cm, but (b) for tall participants willingness ratings were higher in the walk condition than in the run condition at a barrier height of 173 cm. In other words, the task instructions influenced the willingness ratings of both short and tall participants in the hypothesized direction but such an effect occurred at a lower barrier height for short participants than for tall participants.

Consistent with our hypotheses, willingness to pass underneath a barrier was influenced both by the participant's standing height and by their anticipated movement speed. Specifically, at intermediate barrier heights (i.e., barrier heights in the range of participant heights) (a) willingness ratings were higher for short participants than for tall participants and (b) willingness ratings were higher when participants anticipated walking underneath the barrier than when they anticipated running underneath the barrier. Such results are consistent with work showing that both standing height and movement speed influence ducking behavior when passing under a barrier (van der Meer, 1997) and with work showing that anticipated movement speed influences perception of whether an object can be carried through a doorway (Wagman & Malek, 2007). Moreover, Experiment 2 provides preliminary validation of willingness ratings as a measure of sensitivity to constraints on performing a given behavior (before that behavior is attempted).

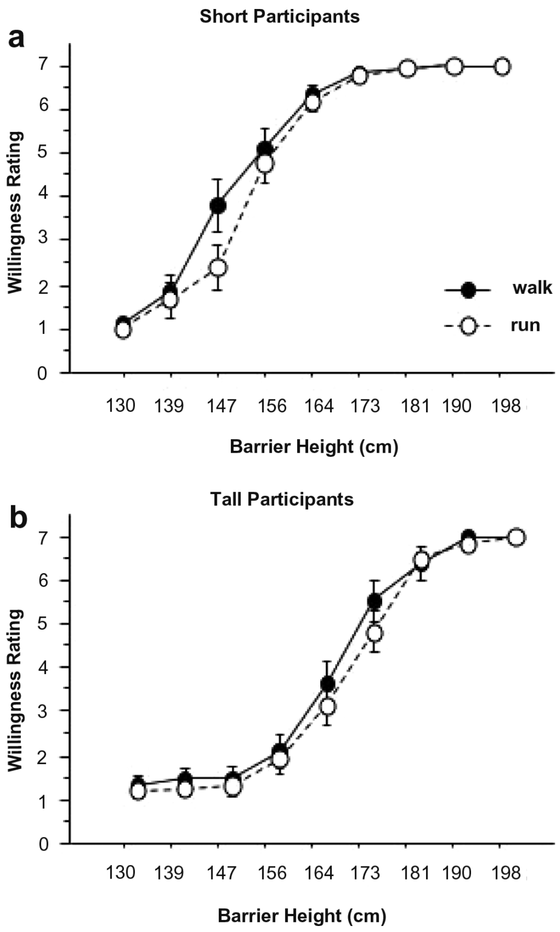

Figure 2. Willingness ratings as a function of barrier height in the walk and run conditions of Experiment 2 for both short participants (a) and tall participants (b). Error bars represent standard error.

Experiments 3a and 3b

Standing height and movement speed influence both the likelihood of successfully passing under a barrier and the potential costs of a failed attempt (i.e., they influence both the likelihood and the potential costs of a collision). Alternatively, the material properties of the barrier do not in and of themselves influence the likelihood of successfully performing this behavior. However, they still influence the costs of a failed attempt (i.e., they influence the potential costs of a collision with that barrier). That is, while perceiver-actors are just as capable of passing under a hard barrier as passing under a soft barrier, *ceteris paribus*, the consequences of colliding with a hard barrier are more severe than those of colliding with a soft barrier. Experiments 3a and 3b investigate whether perceiver-actors are sensitive to such constraints before attempting this behavior.

In Experiments 3a and 3b, we manipulated the material properties of the barrier (hard vs. soft). To maximize the potential cost of a collision with the barrier, participants always reported how willing they would be to run under the barrier. Experiment 3a compared willingness to run underneath a metal barrier and a foam barrier. Experiment 3b compared willingness to run underneath a metal barrier and a rope barrier.

In each case, we expect that willingness ratings will be influenced by both the standing height of the participant and the material properties of the barrier. Specifically, we expect that (a) willingness ratings will be higher for short participants than for tall participants, especially at intermediate barrier heights (i.e., barrier heights that are in the range of participant heights) and (b) willingness ratings will be higher for a soft (i.e., foam or rope) barrier than for a hard (i.e., metal) barrier.

Method

Participants

Participants were recruited from the same population and in the same height categories as in Experiments 1 and 2. In Experiment 3a, 14 participants were in the "tall" group (M = 177.7 cm, SD = 2.8 cm), and 11 were in the "short" group (M = 152.4 cm, SD = 3.6 cm). In Experiment 3b, 14 participants were in the "tall" group (M = 177.0 cm,

$SD = 3.5$ cm), and 18 were in the "short" group ($M = 154.8$ cm, $SD = 3.1$ cm). One of the "short" participants in Experiment 3b was excluded from data analysis due to failure to follow experimenter instructions.

Materials and Apparatus

The stimuli used in Experiment 3a consisted of a hollow aluminum dowel and a "foam dowel" (a thin wooden dowel wrapped in white packing foam), each 91 cm in length. Foam was wrapped around the wooden dowel such that the diameter was the same as the outer diameter of the aluminum dowel (each 2 cm). The foam was secured at each end using clear packing tape. These objects were set into the PVC frame described above. Participants were unaware (a) that the aluminum dowel was hollow and (b) that the foam dowel contained a wooden dowel.

The stimuli used in Experiment 3b consisted of the hollow aluminum dowel and a braided nylon rope (1.5 m in length). The outer diameter of the rope was the same as that of the aluminum dowel (2 cm). The ends of the rope were wrapped with Velcro. When the rope was placed in the PVC frame, these ends were secured to the back of the PVC frame so that the rope was as taut and as level as possible. None of the objects were visible to the participants until set in the frame.

Procedure

The procedure for Experiment 3a was the same as for Experiment 2 except that (a) participants always reported how willing they would be to run underneath the barrier (without ducking their head or bending at their knees or waist) and (b) participants performed this task in two "barrier material" conditions. In the "soft" condition, participants provided willingness ratings after viewing the foam dowel at a particular height in the PVC frame, and in the "hard" condition, participants provided willingness ratings after viewing the metal dowel at a particular height in the PVC frame. Participants completed both barrier material conditions in blocked fashion, and the order of these conditions was counterbalanced across participants. The procedure for Experiment 3b was the same as that for Experiment 3a, except that the nylon rope was substituted for the foam dowel.

Results and Discussion

An initial analysis compared willingness ratings in Experiments 3a and 3b to determine whether there was any difference in ratings for the foam barrier and rope barrier. In this analysis, Experiment (3a or 3b) was treated as a between-participant variable, and barrier material was treated as a within participant variable with two levels – hard (metal) and soft (foam or rope). Willingness ratings were then analyzed with a 2 (barrier material: hard vs. soft) × 2 (participant height group: tall vs. short) × 2 (Experiment: 3a vs. 3b) × 9 (barrier height) ANOVA. A Greenhouse-Geisser correction was applied to all tests involving barrier height. There were no main effects or interactions involving the experiment factor. As a result, the data were collapsed across the two experiments and reanalyzed with a 2 (barrier type: hard vs. soft) × 2 (participant height group: tall vs. short) × 9 (barrier height) ANOVA. Again, a Greenhouse-Geisser correction was applied to all tests involving barrier height.

A main effect of barrier type revealed that overall, willingness ratings were higher for the soft barrier ($M = 4.2$, $SD = 2.7$) than for the hard barrier ($M = 4.0$, $SD = 2.7$), $F(1, 54) = 8.45$, $p < .01$, $\eta_p^2 = .14$. A main effect of barrier height revealed that willingness ratings decreased as barrier height decreased, $F(8, 432) = 490.70$, $p < .001$, $\eta_p^2 = .90$. A main effect of participant height group revealed that willingness ratings were higher for short participants ($M = 4.6$, $SD = 2.6$) than for tall participants ($M = 3.6$, $SD = 2.6$), $F(1, 54) = 32.96$, $p < .001$, $\eta_p^2 = .38$.

An interaction of participant height group and barrier height suggested that the difference in willingness ratings between tall and short participants depended on barrier height, $F(8, 432) = 19.55$, $p < .001$, $\eta_p^2 = .27$ (see Figure 3). Followup t tests (with Bonferroni corrections) confirmed that differences in willingness ratings between tall and short participants occurred only at intermediate barrier heights (i.e., barrier heights in the range of participant heights). In particular, such differences occurred at barrier heights of 156 cm, $t(54) = 4.74$, $p < .001$; 164 cm, $t(54) = 6.65$, $p < .001$; 173 cm, $t(54) = 5.98$, $p < .001$; and 181 cm, $t(54) = 3.72$, $p < .01$ (see Figure 3). The ANOVA revealed no other significant effects (all Fs < 2.0).

Consistent with our hypotheses, willingness to pass underneath a barrier was influenced by both the standing height of the participant and the material properties of the barrier. Specifically, (a) willingness ratings were higher for short participants than for tall participants, especially at intermediate barrier heights (i.e., barrier heights in the range of participant heights) and (b) willingness ratings were higher when participants anticipated passing underneath a

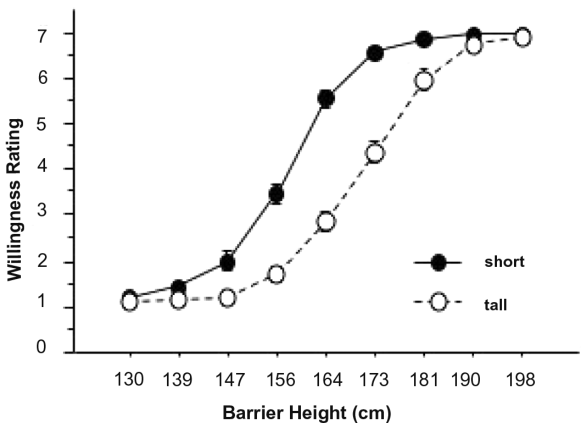

Figure 3. Willingness ratings as a function of barrier height for short and tall participants in Experiments 3a and 3b. Error bars represent standard error.

soft (i.e., either foam or rope) barrier than when they anticipated passing underneath a hard (i.e., metal) barrier. To the best of our knowledge, this is the first demonstration that perceiver-actors are sensitive to how the material properties of a barrier influence the costs of colliding with that barrier before that behavior is attempted.

General Discussion

Completing a goal directed behavior in a safe and efficient manner requires that a perceiver-actor is sensitive to the various constraints on performing that behavior. When attempting to pass underneath a barrier, standing height, movement speed, and the material properties of the barrier itself constrain the likelihood and potential costs of a collision with that barrier. The experiments reported here found that perceiver-actors are sensitive to geometric, kinetic-kinematic, and intentional constraints on this behavior even before this behavior is attempted. Moreover, the results provide initial validation for the use of willingness ratings as a measure of such sensitivity.

Willingness as a Measure of Sensitivity to Constraints on Behavior

Experiment 1 used one of the standard dependent measures for investigating sensitivity to constraints on a particular behavior – participants provided yes or no responses as to whether they would be able to pass under a barrier. This measure showed that perceiver-actors are sensitive to how their standing height influences the likelihood of a collision. As expected, tall participants were more conservative (and exhibited perceptual boundaries at higher barrier heights) than short participants. Such findings are consistent with work showing that taller participants duck at higher barrier heights than shorter participants when actually attempting this behavior (van der Meer, 1997).

However, this measure (i.e., the yes or no response) failed to show that perceiver-actors are sensitive to how their movement speed influences the likelihood (and potential costs of) a collision. Participants were no more conservative (and did not exhibit perceptual boundaries at higher barrier heights) when they anticipated running under the barrier than when they anticipated walking under the barrier. Such findings are inconsistent with work showing that participants duck at higher barrier heights when running than when walking (van der Meer, 1997). It might be the case that, over time, perceptual reports would begin to differ in these two conditions if participants were given opportunities to walk or run toward (or under) the barrier (see Fajen, 2007; Mark, 1987; Oudejans et al., 1996). This may be a topic for future research.

In Experiment 2, we deviated from the standard dependent measures for investigating sensitivity to the constraints on a particular behavior. Rather than reporting whether they *would be able to* pass under the barrier, participants reported how *willing they would be* to attempt this behavior. Doing so served two purposes. First, it provided a more *precise* dependent measure – there are seven possible responses rather than two. Second, it provided a *richer* dependent measure – willingness seems to capture the intention of the perceiver-actor in a way that a yes or no report of whether the behavior is possible does not. That is, willingness takes into account *both* action capabilities (whether the participant *would be able to* perform a particular behavior) and intention (whether the participant would *choose to* perform that behavior). Thus, we feel that this measure is analogous to using movement itself as a dependent measure (e.g., ducking behavior, van der Meer, 1997; shoulder turning, Higuchi et al., 2006; Warren & Whang, 1987, Experiment 1) with the key advantage that it can be used to capture sensitivity to constraints on a given behavior before that behavior is attempted.

Experiments 2 and 3 found that standing height, anticipated speed, and the material properties of the barrier itself influenced willingness to pass under a barrier. Specifically, willingness ratings were higher (a) for short participants than for tall participants (Experiments 2, 3a, and 3b), (b) when participants anticipated walking than when they anticipated running, especially at intermediate bar heights (Experiment 2), and (c) when the barrier was soft than when the barrier was hard (Experiment 3a and 3b).

Geometric, Kinetic-Kinematic, and Intentional Constraints on Perception and Behavior

Clearly, standing height places constraints on passing under a barrier because it influences the likelihood of a collision with the barrier. People taller than the barrier simply cannot pass under the barrier without ducking or bending at the knees or waist. That is, standing height places a geometric constraint on passing under a barrier (i.e., a "hard constraint", see Shaw & Kinsella-Shaw, 1988). Previous work has shown that people are sensitive to this geometric constraint when attempting to perform this behavior (van der Meer, 1997), and the experiments reported here show that people are sensitive to such a constraint even before doing so.

Movement speed places constraints on passing under a barrier because it influences both the likelihood and the potential costs of a collision with that barrier. As movement speed increases, (a) the force of a potential collision increases and (b) the precision with which bodily movements can be controlled decreases (Fitts, 1954). This second point is especially so in bipedal locomotion where increases in movement speed bring about both kinetic and kinematic constraints on passing under a barrier (see above). Previous work has shown that people are sensitive to such kinetic-kinematic constraints when attempting to perform this behavior (van der Meer, 1997), and Experiment 2 showed that people are sensitive to such constraints even before doing so.

Unlike standing height and movement speed, the material properties of the barrier place neither geometric nor kinetic-kinematic constraints on passing under a barrier and do not influence the likelihood of a collision with the barrier. However, they do influence the potential costs of a collision. That is, they provide an *intentional constraint* on passing under a barrier (i.e., a “soft” constraint, see Shaw & Kinsella-Shaw, 1988; see Shaw & Turvey, 1999). Experiments 3a and 3b show that people are sensitive to such intentional constraints before attempting this behavior. Such results are consistent with research showing that perception of environmental properties is, in part, a function of the intention of the perceiver (Witt et al., 2004, 2005; see Proffitt, 2006 for a review).

Researchers from several theoretical approaches have proposed fundamental links between perception and behavior (Clark, 1997; Gibson, 1979; Hommel, Muesseler, Aschersleben, & Prinz, 2001; Mechsner, 2004; Noë, 2004; Proffitt, 2006). The fact that perception is influenced by geometric, kinetic-kinematic, and intentional constraints is consistent with such proposed links. To the extent that perception is for the control of behavior, perception must be forward looking and take into account not only current states of affairs but potential states of affairs as well (Turvey, 1992; Wagman, 2008; Wagman & Malek, 2008). The results of the current experiments highlight that perceiver-actors are sensitive to geometric, kinetic-kinematic, and intentional constraints on performance of a given behavior.

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Jeffrey B. Wagman

Department of Psychology
Illinois State University
Campus Box 4620
Normal, IL 61790-4620
USA
Tel. +1 309 438 7888
Fax +1 309 438 5789
E-mail jbwagma@ilstu.edu