PERCEPTION VS. ACTION: PERCEIVED OBSTACLE CROSSING ABILITY OF FIREFIGHTERS IN PROTECTIVE GEAR

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INTRODUCTION
An individual’s perception of how his or her body fits within the surroundings is a key component for successfully navigating through a cluttered environment that requires moving over, under, or through various obstacles. Possibilities for action, termed “affordances”, are based on individual physical attributes and the constraints of a particular obstacle. Affordance judgments are more accurate when we have previous experience with a task [1] or when our physical features (e.g., height) relevant to the passage are easily compared to the size of aperture. Perception remains accurate even when physical features are artificially enlarged [2] or when the body changes over time due to growth or pregnancy [3].

In firefighting, bulky and heavy equipment is necessary for the health and safety of the firefighter. This equipment can affect balance and gait performance and artificially change the size and location of center of mass of the body [4]. It is unclear how wearing firefighting personal protective equipment (PPE) affects firefighter’s affordance judgments for navigation. In this study, we examined how well firefighters make perceptual judgments about the ability to navigate over, under or through obstacles while wearing their protective gear.

METHODS
Twenty four subjects (23 male, 1 female, age = 28.6 ± 7.9 yrs, height = 182.1 ± 7.2 cm, weight = 90.7 ± 13.9 kg) were recruited by the University of Illinois Fire Service Institute. IRB approval and informed consent were obtained. All subjects were either career or volunteer firefighters. Testing was done while wearing National Fire Protection Association (NFPA) 1971 compliant PPE including boots, protective clothing, helmet, gloves, and a self-contained breathing apparatus (SCBA) tank.

Three obstacles were tested to simulate difficult situations that would challenge a firefighter’s balance or physical ability to pass. Obstacles were always presented in the following order: over, under, through. Participants completed a series of perception-action trials to assess affordance judgment error for each obstacle. The participants first completed the perception trials to prevent action trials from informing perception [1].

The ‘through’ obstacle was a doorway with an adjustable width (height 228 cm), attached perpendicular to a false wall (height 244 cm, width 122 cm). The ‘over’ and ‘under’ obstacles consisted of vertical uprights set 122 cm apart to simulate the average width of a hallway. Each upright had a sliding carriage that held cross bars in place. The ‘over’ obstacle (max height 100 cm) had two PVC cross bars set 10 cm apart, while the ‘under’ (max height 185 cm) only had a single crossbar. Obstacles could be adjusted to a resolution of 1 cm. Subjects began every trial standing 2.5 m away from the front of each obstacle.

For perception trials, subjects were asked if they thought they could transverse the given obstacle without committing an error. Action trials involved the subjects attempting to actually pass the obstacle without committing an error. Errors were defined as: touching or knocking off the cross bar(s) (over, under), touching hands or knees to the ground (under), or removing the SCBA tank or other shifting of gear (through). Subjects were told to perform the trials at “fireground pace”, i.e. acting as quickly as safely possible without running, and to complete trials even if an error was committed. These obstacles and definitions were designed to push the limits of subjects’ balance and assess their ability to account for the size of the SCBA tank.

To determine the perceived and actual ability to pass the obstacles, affordance functions were fit to the data based on a normal distribution [1]. The first
4-8 trials began with a binary search method to gain an estimate of the affordance threshold (i.e. the point where they could no longer pass the obstacle). The remaining 6 trials were performed at two points equidistant (0.5 cm) from the estimated affordance threshold. The 50% values of the cumulative distribution functions fit to these data were considered to be the affordance threshold for either perception or action trials.

Statistical differences between perception and action affordance thresholds were assessed using pairwise t-tests (SPSS 20.0; IBM Corp, Armonk, NY). Each threshold value was normalized to relevant body features for each obstacle. These included leg length (over), body height (under), and chest depth (through). Additionally, perceptual judgment error was determined to be the difference between the perceived and action affordance thresholds. Perceptual overestimation of abilities (i.e. saying “yes” to a value that was impassible) was considered to be positive value. Underestimation (i.e. saying “no” to a value that was passable) was considered to be negative.

RESULTS AND DISCUSSION
Significant differences were found between perception and action affordance thresholds for the ‘under’ (p < 0.001) and ‘through’ (p = 0.001) obstacles (Figure 1). However, judgment error existed for each obstacle across subjects (Table 1). For example, judgment error for the ‘under’ obstacle was 15 ± 9.5 cm because all but one subject overestimated ability to pass under the obstacle. Typically, subjects failed by having the top of the SCBA tank or the back of the helmet knock off the crossbar. Interestingly, 15 cm equates to the approximate depth of the SCBA tank, suggesting subjects did not accurately consider the depth of the tank while generating their perceptions. In contrast, there was a general underestimation of abilities in the through obstacle (-4.2 ± 5.3 cm) with only 4 subjects overestimating their abilities. This could be due to a lack of understanding of how movable the SCBA pack was on their back while forcing themselves through the doorway.

A small underestimation of abilities was observed in the ‘over’ obstacle (-0.5 ± 9.5 cm; Table 1). However, the large amount of variability indicates almost the same amount of underestimation and overestimation was present. This was revealed when the absolute value of error was taken, which indicated that nearly 8 cm of judgment error was present.

CONCLUSIONS
These data suggest that firefighters do not have an accurate perception of their abilities while traversing obstacles in their firefighting PPE. Future studies should focus on specific tasks commonly encountered on the fireground.

REFERENCES

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Table 1 Judgment errors (relative and absolute) by obstacle type. Positive value corresponds to perceived overestimation actual ability. Notice judgment error becomes apparent in the over obstacle when the absolute value is taken.

<table>
<thead>
<tr>
<th>Judgment Error (mean ± SD)</th>
<th>Over</th>
<th>Under</th>
<th>Through</th>
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<tbody>
<tr>
<td>Judgment Error (mean ± SD)</td>
<td>-0.5 ± 9.5 cm</td>
<td>15 ± 9.5 cm</td>
<td>-4.2 ± 5.3 cm</td>
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<tr>
<td>Absolute Judgment Error (mean ± SD)</td>
<td>7.9 ± 5.3 cm</td>
<td>15.2 ± 9.2 cm</td>
<td>5.5 ± 3.9 cm</td>
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