Can one’s ability to perform an action, such as hitting a softball, influence subsequent perception? According to the action-specific account, perception of spatial layout is influenced by the perceiver’s abilities to perform the intended action. Alternative accounts are that purported effects are due to non-perceptual processes instead such as response bias. Despite much confirmatory research on both sides of the debate, researchers who promote a response bias account have never used the most robust action-specific effect in their research. Conversely, researchers who promote a perceptual account rarely use the opposition’s preferred test for response bias, namely the use of post-experiment surveys. The current experiment rectifies this. We found that even for people naïve to the experiment’s hypothesis, their ability to block a moving ball affected perceived ball speed. Moreover, when participants were explicitly told the hypothesis and instructed to resist it, the effect of ability still affected perceived ball speed.

The perceptual experience of the environment gives the impression that the world exists as it is perceived. Yet, vision scientists understand that there are many inaccuracies and biases within perceptual processes that taint the resulting experience. The scientist’s task is to explore and understand these biases. In each case, the scientist must determine whether the bias genuinely influences perception. According to the action-specific account of perception, action is one of the biases that has a genuine influence (Proffitt, 2006; Proffitt & Linkenauger, 2013; Witt, 2011, 2017). For example, softball players who are hitting better than others see the ball as bigger (Gray, 2013; Witt & Proffitt, 2005). Hills look steeper and distances look farther to perceivers who would have to exert more effort to traverse the space (Bhalla & Proffitt, 1999; Sugovic, Turk, & Witt, 2016; Taylor-Covill & Eves, 2014, 2016). This research shows that the perceiver’s ability to act influences spatial perception. However, this research has been challenged on the grounds of whether action exerts a genuine influence on perception (Durgin et al., 2009; Loomis, 2016; Shaffer, McManama, Swank, & Durgin, 2013; Woods, Philbeck, & Danoff, 2009). Alternative explanations are that the reported findings are due to non-perceptual processes such as response bias. Some researchers have gone so far as to say that factors such as action can never penetrate perceptual processes (Firestone & Scholl, 2016).

Among those who have recently challenged that action-specific effects are perceptual, the most highly recommended strategy is the use of post-experiment surveys (Firestone & Scholl, 2016). The idea is to separate out participants who were discerning of the experiment’s hypothesis from those who were naïve (Durgin, Klein, Spiegel, Strawser, & Williams, 2012). If only the participants who correctly surmised the hypothesis show the effect of action on perceptual judgments, this is strong evidence that the effect is driven by response bias. In contrast, if the influence of action on perceptual judgments is independent of whether or not the participant could accurately deduce the purpose of the experiment, this is strong evidence against a response bias account. Given that this strategy is so highly recommended by critics of the action-specific account, it is surprising that it has not been implemented within the Pong task, which is the task has been the most thoroughly investigated within the action-specific field. In the Pong task, participants attempt to block moving balls with variously sized paddles. When playing with a smaller paddle, which makes it harder to block the
ball, participants estimate the ball as moving faster than when they play with a bigger paddle (Witt & Sugovic, 2010, 2012). Despite substantial evidence within the Pong task that the effect is genuinely perceptual (King, Tenhundfeld, & Witt, in press; Witt, 2017; Witt & Sugovic, 2012, 2013a, 2013b; Witt, Sugovic, & Dodd, 2016; Witt, Sugovic, Tenhundfeld, & King, 2016), the research has never once questioned participants afterwards to determine if the hypothesis is as obvious as it may seem. This important gap is filled here.

**Experiment 1**

**Method**

**Participants.** Sixteen participants were recruited via the psychology participant pool and received course credit. Based on previously reported effect sizes (Witt & Sugovic, 2010, 2013b), a power analysis indicated that 9 participants are needed to achieve 80% power to show an effect of paddle size on estimated speed.

**Apparatus and Stimuli.** The experiment took place on a desktop computer with a 19” display. The background was either red or blue. The ball was a white circle that was 1 cm in diameter. The paddle was a white rectangle that was 0.86 cm wide and was either 1.86 cm or 9.28 cm tall on each trial. Participants used a joystick to control the movements of the paddle and to make their responses about ball speed.

**Procedure.** Participants completed two brief training phases followed by a test phase. During the first training phase, participants were exposed to the slow and fast anchor speeds. Text on the screen indicated if the ball would be slow or fast. The ball then traveled at the slow (18 cm/s) or fast (74 cm/s) speed horizontally with no vertical displacement from the left to the right of the screen. Each speed was shown three times and order was randomized. During the second training phase, participants were tested on their ability to classify the anchor speeds. The ball appeared on the left side of the screen. Participants pressed the trigger on the joystick to begin the trial. At this point, the ball traveled across the screen at the designated speed. The ball traveled along a diagonal and reversed the vertical direction whenever it reached the top or bottom of the display and also changed directions at random throughout the trial. Participants could move the joystick to control the vertical location of the paddle. If the paddle was positioned to intersect the ball, the ball stopped on the paddle. Otherwise, the ball continued past the paddle and past the edge of the screen. After each attempt, regardless of whether the ball was successfully blocked or not, participants were prompted with a screen that displayed “slow or fast?” and remained until a response was made. Participants indicated if the ball moved more like the slow speed or more like the fast speed by pressing the corresponding button on the joystick. Each block contained 24 trials (6 test speeds x 2 paddle sizes x 2 background colors). Order within block was randomized. Participants completed 12 blocks.

After completing the Pong task, participants were prompted with questions on the display and they wrote their answers on a blank piece of paper. The questions are shown in Table 1. Responses are shown in the on-line supplementary material.
Table 1. Questions included in the post-experiment survey.

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<thead>
<tr>
<th>Question number</th>
<th>Question</th>
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<tbody>
<tr>
<td>1</td>
<td>Did you spend any time trying to figure out the purpose of the experiment? If so, please indicate approximately how much time.</td>
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<td>2</td>
<td>What do you think the purpose of this study was?</td>
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<td>3</td>
<td>What aspects of the task seemed most important?</td>
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<td>4</td>
<td>Did you use any particular strategies during the experiment?</td>
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<td>5</td>
<td>The purpose of the study was to determine the factors that influence the perception of speed. What factor or factors do you think we were interested in? Do you think these factors should make the ball look faster or slower?</td>
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<tr>
<td>6</td>
<td>Do you think the size of the paddle changed how fast the ball looked? If so, how?</td>
</tr>
<tr>
<td>7</td>
<td>Do you think missing the ball changed how fast the ball looked? If so, did missing the ball make it appear faster or slower?</td>
</tr>
<tr>
<td>8</td>
<td>In this study, we wanted to know whether the size of the paddle would change the perceived speed of the ball. Did you ever suspect that this was the purpose of the study</td>
</tr>
</tbody>
</table>

Results

As expected, paddle size significantly influenced ball blocking success. Mean proportions of balls successfully blocked for each participant for each paddle size were submitted to a paired-samples t-test. Paddle size significantly influenced proportion of balls successfully blocked, $t(15) = 43.41$, $p < .001$, $d_{m} = 4.00$, Bayes factor > 1000 (small: $M = .45$ proportion ball successfully blocked, $SD = .06$; big: $M = .92$, $SD = .04$). All Bayes factors were calculated using the BayesFactor R package and a Cauchy prior.

Speed judgments were summarized by calculating the point of subjective equality (PSE) for each participant for each paddle size from the slopes and intercepts of binary logistic regressions (see Figure 1 and on-line Supplementary Material). The PSEs for each paddle size were submitted to a paired-samples t-test. Paddle size had a significant influence on the PSEs, $t(15) = 5.73$, $p < .001$, $d_{m} = .50$, Bayes factor = 736 (Small: $M = 41.43$ cm/s, $SD = 3.06$; Big: $M = 45.07$, $SD = 3.29$; $M_{diff} = 3.64$ cm/s, $SD_{diff} = 2.54$). This replicates the typical effect found in this Pong task. The difference between the PSEs with the big and small paddles is known as the Pong effect.
Next, we analyzed the survey data. Of the 16 participants, 12 (75%) made no mention of the size of the paddle when asked an open-ended question about the purpose of the experiment (Question 2). We analyzed the data from just these 12 participants (see Figure 2 and Table S2), and found a significant effect of paddle size on PSEs, \( t(11) = 4.44, p = .001, d_{rm} = .56, \) Bayes Factor = 43 (Small: \( M = 41.74 \text{ cm/s}, SD = 3.16; \) Big: \( M = 45.47, SD = 3.40; \) \( M_{diff} = 3.73, SD_{diff} = 2.92 \)). Even participants who did not surmise the purpose of the study when asked an open-ended question still revealed a strong Pong effect.

We further explored these 12 participants regarding their answers to a more specific question. Question 5 explicitly told participants that the experiment was about factors that influence perceived speed and asked what factors might be of interest to the researchers. Of these 12 participants, 8 did not mention the paddle size as being a relevant factor of interest to the researchers. The data from these 8 naïve participants were analyzed. Paddle size still influences the PSEs, \( t(7) = 3.01, p = .02, d_{rm} = .40, \) Bayes Factor = 3.83 (Small: \( M = 41.72 \text{ cm/s}, SD = 3.63; \) Big: \( M = 44.94, SD = 3.73; \) \( M_{diff} = 3.23, SD_{diff} = 3.03 \)). We were unable to analyze the data based on responses to Question 6. Several participants responded that the ball appeared to move faster when the paddle was small. It is unclear whether this response reflected an awareness of the study’s hypothesis or an awareness of the paddle’s effect on perceived ball speed. Without being able to differentiate between discernment of the study’s purpose versus experience of the effect itself, any results would be uninterpretable regarding a potential role for response bias.

The last question of the survey explicitly stated the hypothesis and asked participants if they ever suspected this was the purpose. Less than half of the participants (\( n = 7 \)) stated yes. Of the remaining 9 participants, 5 said no and 4 were noncommittal with statements such as “kind of” or “a little, but not too much”. One of these 4 stated that they “tried to not let paddle size affect what speed [they] thought it was.” When analyzing the data from these 9 participants, paddle size still influenced the PSEs, \( t(8) = 3.65, p = .006, d_{rm} = .52, \) Bayes factor = 9.35.

Figure 1. Mean proportion of “fast” responses as a function of ball speed and paddle size for one representative participant. Curves represent binary logistic regressions for each paddle size. Plots for each participant available in on-line supplementary materials.
Figure 2. The Pong effect for each participant in Experiment 1 is plotted as a function of whether they mentioned paddle size when asked an open-ended question about the purpose of the experiment (Discerning), mentioned paddle size when asked what factors the researchers might think influence perceived ball speed (Suspicious) or did not mention paddle size for either question (Naive). The Pong effect was calculated as the PSE with the big paddle minus the PSE with the small paddle. A Pong effect of 0 indicates no effect of paddle on PSEs. A positive Pong effect indicates that the ball appeared faster when the paddle was small than when the paddle was big.

The data showed that not many people inferred the purpose of the experiment. Only 25% even mentioned paddle size when asked an open-ended question about the experiment, and of the remaining 75%, only 33% mentioned paddle size when asked for specific factors that might be hypothesized to affect perceived speed. These data suggest that the Pong task may not be as obvious to participants as it may seem to researchers well-versed in the literature (see also Tenhundfeld & Witt, 2017 for similar naivety with respect to perceived distances on hills). Moreover, the action-specific effect of paddle size on estimated speed was not driven by response bias based on inferring the study’s purpose. Even when we excluded participants who correctly inferred the purpose of the experiment, the Pong effect still emerged.

Experiment 2

Experiment 1 showed that there were no systematic differences between participants who were able to discern the purpose of the experiment and those who were native to the study’s purpose. In Experiment 2, we examined whether participants could resist the Pong effect after being warned about it.

Method

Participants. Seventeen students volunteered in exchange for course credit. We initially ran 16, but one did not complete the survey at the end, so we ran an additional participant. Given that all participants were informed of the study’s purpose, all were included in the analysis.
Stimuli, Apparatus, & Procedure. Everything was the same in Experiment 1 except that participants received an additional instruction at the beginning of the test phase. The new instruction was presented on the screen and stated the following: “Participants tend to report that the ball is faster when the paddle is small even though the balls move, on average, at the same speeds for both paddles. We want to know whether people can resist this tendency. Please report how the speed of the ball APPEARS without allowing your responses to be biased by extraneous factors like the size of the paddle.”

Results

PSEs were calculated from binary logistic regressions for each participant for each paddle size condition. These were submitted a paired-samples t-test. Paddle size significantly influenced PSEs, \(t(16) = 3.51, p = .003, d_{rm} = 0.66, \text{Bayes Factor} = 14\) (Small: \(M = 46.12\) cm/s, \(SD = 3.88\); Big: \(M = 48.99, SD = 4.67; M_{\text{diff}} = 2.87\) cm/s, \(SD_{\text{diff}} = 3.37\)). As shown in Figure 3, the Pong effect emerged even when participants were warned about the Pong effect and explicitly instructed to resist it.

![Graph showing Pong effect](image)

**Figure 3.** The Pong effect for each participant in Experiment 2 is plotted as a function of their rank order. The Pong effect was calculated as the PSE with the big paddle minus the PSE with the small paddle. A Pong effect of 0 indicates no effect of paddle size on PSEs. A positive Pong effect indicates that the ball appeared faster when the paddle was small than when the paddle was big.

The instructions to resist the Pong effect were not sufficient to eliminate the Pong effect. They were not even sufficient to lessen the effect. The Pong effect was not significantly reduced in Experiment 2 compared with the Pong effect in Experiment 1, \(t(31) = 0.84, p = .41, d = .31, \text{Bayes Factor} = .34\). In contrast, the instructions were effective at eliminating the effect of background color on estimated speed. PSEs were calculated for each background color for each participant in both experiments. In Experiment 1, participants reported the ball as moving faster when the background was red than when it was blue, \(t(15) = 4.67, p < .001, d_{rm} = .64, \text{Bayes Factor} = 115\). In contrast, in Experiment 2 for which participants were told to resist allowing their responses to be
biased by extraneous factors, background color did not influence estimated speed, $t(16) = -1.45, p = .166, d_{rm} = .19$, Bayes Factor $= .48$. If anything the pattern reversed itself, suggesting perhaps an over-correction (see Figure 4). Assuming any effect of background color on estimated speed was due to response bias, the data show that the instructions were sufficient to eliminate response biases associated with background color. This further highlights the robustness of the Pong effect even when pitted against instructions that were effective at eliminating response bias.

![Figure 4](image)

**Figure 4.** The color difference score is calculated as the PSE when the background is blue minus the PSE when the background is red. The color difference score is plotted for each participant for each experiment. A color difference score of 0 indicates no effect of background color on PSEs. A positive color difference score indicates that the ball was estimated as moving faster when the background was red than when it was blue.

**General Discussion**

By some accounts, perception is a modular system that involves encapsulated processes (Firestone & Scholl, 2016; Fodor, 1983; Pylyshyn, 1999, 2003). According to this view, external factors such as cognition or action cannot penetrate these processes, and thus, cannot influence what is seen. The action-specific account of perception challenges this view of perception. Prior research demonstrated that a person’s ability to block a moving ball influences perceptual judgments of ball speed. Despite a plethora of studies that have ruled out alternative, non-perceptual explanations (Witt, 2017), this work could be criticized for not implementing a post-experiment survey. In completing this critical step, Experiment 1 supports the claim that a person’s ability to act can exert a genuine influence on the perceptual experience. This claim was further supported by the results from Experiment 2, for which action’s effect on perception persisted despite instructions to resist any tendency to report that the ball is faster when the paddle is small than when the paddle is big. The results suggest that this action-specific effect is perceptual and is even immune to knowledge about it. Just as knowledge about a visual illusion (such as knowing that the two tables are the same size in the Shepard’s table illusion) does not lessen the illusion, knowledge of the effect of paddle size on estimated speed also does not lessen the bias on perceived speed.

The data on the Pong effect suggest a role for top-down influences on perception. In the case of action’s influence on spatial perception, the effects need not depend on explicit knowledge, however. Action’s influence is likely rooted in unconscious motor processes, rather than thinking or reasoning.
about action. For example, golf performance, but not subjective ratings of golf performance, correlated with perceived hole size (Witt, Linkenauger, Bakdash, & Proffitt, 2008). As another example, physical body weight (but not subjective ratings of body size) related to perceived distance (Sugovic et al., 2016). Indeed, the results from Experiment 2 suggest that knowledge of the bias does not help to lessen the effect of paddle size on perceived ball speed. To understand the mechanism driving action-specific effects, we must determine both the source of the information about action and how it exerts its influence. The source of information related to action may derive from sensors that detect physical states of the body such as its size and location (via proprioceptors) or hunger and fatigue levels (via interoceptors). If perception involves the integration of information extracted from body- or action-based sensory systems with information extracted from visual or auditory sensory systems, action-specific effects may be best considered as a new kind of multimodal effect (Witt & Riley, 2014). In other words, action-specific effects may result from the integration of information from sensors that detect the internal environment and sensors that detect the external environment. If so, action-specific effects would demonstrate that the perceptual experience of spatial layout is relative to the perceiver’s own body and abilities.

Author Note

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References


On-line Supplementary Materials

The on-line supplementary materials will include Figure S1 and S2 (below), Table S1 (below), and a PDF of all of the participants’ survey responses (separate). The Figures and Table are included here for ease of readability.

Figure S1. Mean proportion of “fast” responses as a function of ball speed and paddle size for each participant. Curves represent binary logistic regressions for each paddle size. Participant number is in top left corner of each plot.
Table S1. Overview of participants who were included in each of the analyses. An “x” indicates they were included in the analysis for Question 2 (Q2), Question 5 (Q5), and Question 8 (Q8).

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<tr>
<th>Subject</th>
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<th>Q5</th>
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Figure S2. Mean proportion of “fast” responses as a function of ball speed and paddle size for each participant in Experiment 2. Curves represent binary logistic regressions for each paddle size.