

The Pong Effect as a Robust Visual Illusion: Evidence From Manipulating Instructions

Emily L. Laitin and Jessica K. Witt 

Colorado State University, United States

Abstract

Visual perception is not always veridical but can be influenced by factors such as ease of acting, energetic cost, and even body type of the observer. This notion is called action-specific perception. Several effects of action capability on visual perception have been found, but there is much controversy as to whether these effects are truly perceptual. Because perception cannot be measured directly, resolving the controversy relies on ruling out alternative explanations through systematic testing. We combined one of the most robust action-specific effects (the Pong effect) with one of the primary suggestions for exploring an alternative explanation, namely whether the effect persists across instructions that emphasize different aspects of the task. The Pong effect was robust to the type of instructions. The results provide critical evidence that the Pong effect is truly perceptual, furthering the argument that a person's ability to act can influence visual perception.

Keywords

perception/action, pointing/hitting, spatial vision, spatial cognition

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Imagine getting home after a long day of traveling and carrying heavy luggage. The only task left to complete is a simple stairwell up to bed. Suddenly, the familiar set of stairs appears longer and steeper than memory had held them. What might seem like a weary traveler's mind playing tricks is actually a psychological phenomenon: Spatial perception is influenced by one's ability to act.

Corresponding author:

Jessica K. Witt, Department of Psychology, Colorado State University, Behavioral Sciences Building, Fort Collins, CO 80523, United States.

Email: Jessica.Witt@colostate.edu

Increasing evidence suggests perception of an environment can be influenced by one's ability to act (Witt, 2017). This action-specific account of perception challenges current theories of vision by showing that one's visual experience is influenced by action-based factors such as performance and energetic costs. For example, softball players hitting better than others judged the ball as bigger (Gray, 2013; Witt & Proffitt, 2005). The idea that a person's ability to act can influence spatial perception entails two fundamental implications. The first is that the goal of perception is not to achieve geometric veracity but rather to scale the surrounding environment in terms of the body and its behavioral repertoire (Proffitt & Baer, 2020; Proffitt & Linkenauger, 2013). The second is that the information for perception draws from information about the body and its performance capabilities. This highlights a whole new category of information for spatial perception.

Before revising theories of vision to accommodate such effects, it is imperative to ensure the effects are indeed perceptual. An alternative explanation is that the effects are due to postperceptual judgment-based processes (Firestone & Scholl, 2016; Woods et al., 2009). Related to the softball study, it is possible that batters *perceived* the ball similarly regardless of their success, but those who hit better subsequently *judged* the ball as bigger. If the effects showing a relationship between performance and spatial perception are due to judgments, rather than perception, action-specific effects have no consequences for theories of vision. However, if the effects are due to a difference in perception, action-specific effects have implications for both the information for spatial perception as well as its overarching goal.

Perception is an internal state and cannot be measured directly. Thus, to prove an effect is perceptual, one must systematically examine and subsequently eliminate all possible non-perceptual explanations. One such effect that has been systematically examined is the Pong effect (Witt & Sugovic, 2010). When playing a computer game similar to Pong, participants estimated the speed of the ball as moving faster when using a small paddle than a large paddle. According to the action-specific account, the ball is judged as faster because it looks faster when it is harder to block due to the small paddle than when it is easier to block due to the large paddle. Alternatively, the difference in speed judgments could be due to a judgment-based effect. For example, participants could be implicitly judging how hard it is to block and converting these feelings of difficulty into judgments of speed (Firestone & Scholl, 2016).

One strategy for differentiating these options is manipulating the instructions to emphasize visual versus nonvisual information (Woods et al., 2009). For example, the action-specific effect that distances look farther when throwing a heavy ball versus a light ball (Witt et al., 2004) was eliminated when instructions emphasized the visual information and present only when instructions emphasized nonvisual information (Woods et al., 2009). The idea is that a target does not *look* farther away when people throw a heavy ball, but the target *feels* farther, and these feelings penetrate perceptual judgments (Fajen & Phillips, 2013). The nonvisual instructions invite more intrusion from feelings or judgment-based processes, whereas the apparent instructions prevent such intrusions.

The strategy of using instructions that emphasize nonvisual factors versus instructions that emphasize reporting how the object appears was one of the specific recommendations made by Firestone and Scholl (2016). Their target article provided an excellent overview of the various ways that seemingly top-down effects on perception could instead be supported by nonperceptual explanations. These illustrations were accompanied by corresponding demonstrations. What the article lacked, however, was an application of their strongest arguments against the strongest cases for top-down effects. If nonperceptual explanations can account for *all* action-specific effects, we must concede that action does not influence spatial perception. But if nonperceptual explanations can only account for the weakest

demonstrations but cannot explain, for example, the Pong effect, this would demonstrate that theories of spatial vision must accommodate action’s influence on perception. The current article rectifies this gap: We applied one of Firestone and Scholl’s core recommendations to one of the action-specific effects that has thus far resisted nonperceptual explanations: the Pong effect.

Method

Participants

Thirty-four students were recruited through the psychology department’s participant pool. They provided informed consent prior to completing the experiment. A power analysis shows that a sample size of 12 participants is needed to achieve 80% power to detect the Pong effect ($d_z = .77$, paired-samples and one-sided t test). If using the apparent instructions does not eliminate the Pong effect, we will have sufficient power to detect it.

Stimuli and Apparatus

The stimuli were presented on a 19" computer monitor with a black background. A joystick was used to control the paddle and estimate ball speed. The stimuli consisted of a ball, which was a white circle 1 cm in diameter, and a paddle, which was 0.86 cm wide and set to 1 of 3 heights (1.86, 3.72, 9.28 cm). The paddle was placed on top of a white rectangle that was the height of the display and the same width of the paddle so that only the top and bottom black borders of the paddle were visible. The ball moved at 1 of 6 speeds ranging from 26 to 67 cm/s.

Procedure

Participants were first trained on the anchor speeds. Training consisted of an exposure block and an identification block. During the exposure block, text on the screen indicated that the ball would move at the slow speed or at the fast speed, and then the ball moved horizontally with no vertical displacements across the display either at 18 cm/s or 74 cm/s. There were six exposure trials, and order was randomized. During the identification block, there was no text to identify the speed. The ball moved at either the slow or the fast speed, and participants indicated the speed by pressing the left button on the joystick for slow and the right button on the joystick for fast. There were six identification trials, and order was randomized.

Participants were assigned to one of the two instructional groups in alternating order. Participants assigned to the *apparent* condition were told to report the speed of the ball as it appears to be moving (see Table 1). Participants assigned to the *nonvisual* condition were told to report how fast the ball feels, taking nonvisual factors into account.

Table 1. Text for Each Instruction Condition.

Condition	Instructions
Apparent	We want you to report how fast the ball APPEARS to be moving. If the ball appears to be moving slow, report slow. If the ball appears to be moving fast, report fast.
Nonvisual	We want you to report how fast the ball FEELS to be moving, taking into account any nonvisual factors. If the ball feels like it is moving slow, report slow. If the ball feels like it is moving fast, report fast.

During the test trials, a ball moved across the screen at one of six speeds. The ball moved along a diagonal and moved at steeper angles for the slower speeds. The ball reversed the vertical component of its direction when it reached the top or bottom of the display and at various random times throughout its path. Participants used a joystick to manipulate a paddle to block a ball moving across the screen (see Figure 1). The paddle ranged in size from small, medium, and big and was placed on top of a white background to minimize visual differences across conditions. When participants successfully positioned the paddle to block the ball, the ball stopped on the paddle. When the paddle was incorrectly positioned, the ball continued past the paddle and past the edge of the screen, thereby signaling a miss. After each attempt to block the ball, participants estimated ball speed by judging whether the ball moved more like the slow or fast anchor speeds shown at the beginning. They made their response by pressing the left or right buttons on the joystick to indicate “slow” or “fast,” respectively. Participants completed 144 trials (3 paddle sizes $\times$ 6 ball speeds $\times$ 8 replications). Order was randomized.

Results

As intended by design, participants were more successful at blocking the ball with the big paddle (90% success) than the medium (65%) or small (43%) paddles. Blocking success did not vary by instruction condition (see <https://osf.io/b6dwr/> for details).

We analyzed the speed judgment data with a logistic generalized linear mixed model. The dependent factor was estimated speed, which was coded as 0 for slow and 1 for fast. The fixed effects were ball speed (which was mean-centered), paddle size (coded as -0.5 , 0 , 0.5 for small, medium, and big, respectively), trial outcome (coded as -0.5 for miss and 0.5 for success), and instruction condition (coded as -0.5 for apparent and 0.5 for nonvisual).



Figure 1. The experimental setup.

The fixed effects also included the interactions between instruction condition and each of the other fixed effects. Random effects for participant were included in the model, including intercepts and slopes for ball speed. Including additional slopes for the random effects reduced model fit (as indicated by higher Bayesian information criterion scores). Model fit was also worse when using a Gaussian or Weibull distributions.

The main effect for speed was significant, $z = 20.38$, $p < .001$, estimate = 0.20, $SE = 0.01$. As expected, participants estimated the ball as moving faster when the ball was moving faster. The main effect of instruction condition was not significant, $z = 0.36$, $p = .72$, estimate = 0.10, $SE = 0.29$. Participants in one instruction condition did not estimate the ball as moving faster relative to participants in the other instruction condition. The interaction between ball speed and instruction condition was not significant, $z = 0.36$, $p = .72$, estimate = 0.01, $SE = 0.02$.

Critically, the main effect for paddle size was significant, $z = -8.69$, $p < .001$, estimate = -0.76, $SE = 0.09$. As paddle size increased, the estimated speed decreased. The interaction between paddle size and instructions was not significant, $z = 0.48$, $p = .63$, estimate = 0.08, $SE = 0.17$, $BF_{01} > 80$ (BF_{01} = Bayes factor in favor of the null hypothesis over the alternative hypothesis; formula from Masson, 2011). Instructing participants to take into account nonvisual information did not increase the magnitude of the Pong effect. If anything, the magnitude of the Pong effect was larger in the apparent condition than the nonvisual condition, although this difference was not significant. This result is consistent with little-to-no role for judgment-related processes in the Pong effect (see Figures 2 and 3).

One possible interpretation is that our instruction manipulations were ineffective for impacting judgments. As a manipulation check, we assessed whether the instructions influenced the effect of trial outcome on estimated speed. Trial outcome, which refers to whether the ball was successfully blocked or missed, is unknown until the end of the trial, at which point, the ball is no longer moving or near the end of its path. Participants estimated the ball as moving faster after it was missed than after it was blocked, $z = -6.34$, $p < .001$, estimate = -0.47, $SE = 0.07$. This effect of trial outcome on judged speed is assumed to be a judgment-based effect given the paucity of visual information about ball speed once trial outcome is known (Witt et al., 2017; Witt & Sugovic, 2012). Given that instructions are thought to impact judgment-based effects, we assessed the interaction between trial outcome and instructions on speed judgments as a manipulation check.

The interaction between trial outcome and instructions was significant, $z = -2.48$, $p = .013$, estimate = -0.37, $SE = 0.15$. Trial outcome had a bigger impact on estimated speed when participants were instructed to take into account nonvisual information than when they were instructed to report on how the ball appeared to move. This result provides support that the instruction manipulation was effective at increasing judgment-based effects (cf. Firestone & Scholl, 2016; Woods et al., 2009). That the known judgment-based effect of trial outcome was affected by the instruction manipulation helps us to interpret the null effect between instruction condition and paddle size. In other words, it increases confidence that the lack of influence of instructions on the Pong effect was not due to ineffective instructions. However, the apparent instructions failed to eliminate the trial outcome effect altogether, as shown by a significant main effect for trial outcome in the apparent condition, $z = -2.73$, $p = .006$, estimate = -0.29, $SE = 0.10$. Given the assumption that the trial outcome effect is purely a judgment-based effect, this suggests that the apparent instructions were not fully effective at eliminating judgment-based effects. Instead, the outcomes suggest that the nonvisual instructions further enhanced judgment-based effects. By showing an increase in the trial outcome effect, but not the Pong effect, when using

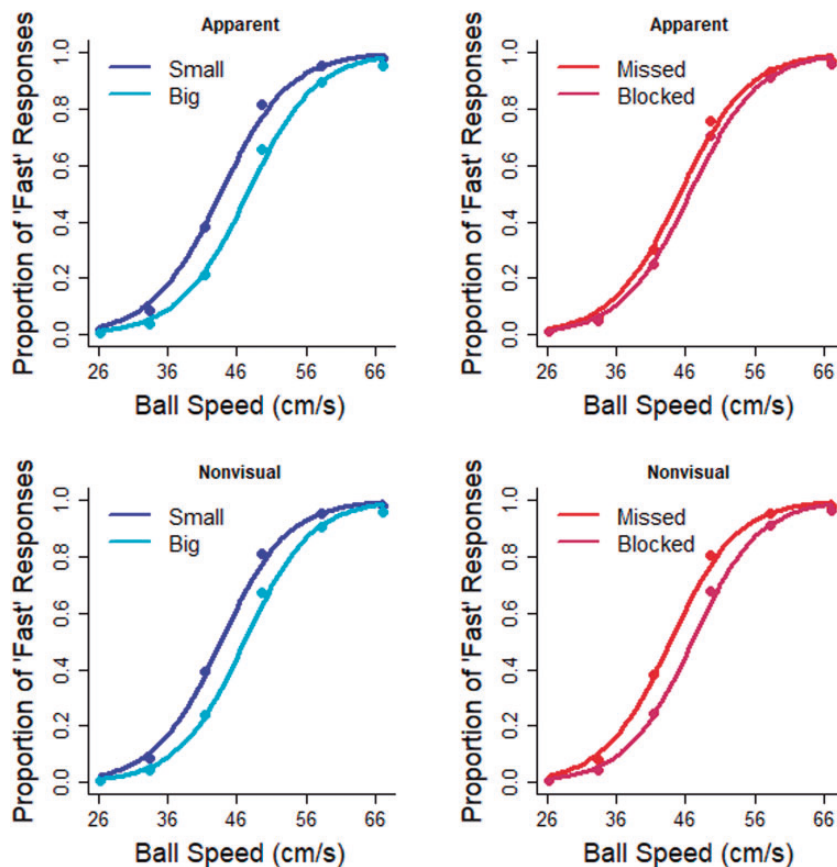


Figure 2. Estimated logistic regressions based on the model coefficients showing the proportion of balls labeled as fast as a function of ball speed for each instruction condition. The left column shows the comparison between the small and big paddles. For ease of presentation, the medium paddle is not shown. The right column shows the comparison between missed and blocked balls. Points represent marginal means. *Note.* Please refer to the online version of the article to view the figure in colour.

nonvisual instructions, the data support the claim that the Pong effect is not due to judgment-based processes.

General Discussion

Can a person's ability to perform an action influence spatial perception? According to the action-specific account, perception of spatial characteristics of an object will correspond to the person's ability to act on them. This means that the same visual information can lead to different perceptions depending on the person's behavioral capabilities. If these effects are truly perceptual, the implications are that theories of spatial perception need to account for a new source of information, namely information related to the person's ability to act, and theories must accommodate that the goal of perception is not geometric constancy but rather to relate the surrounding environment to the perceiver's abilities.

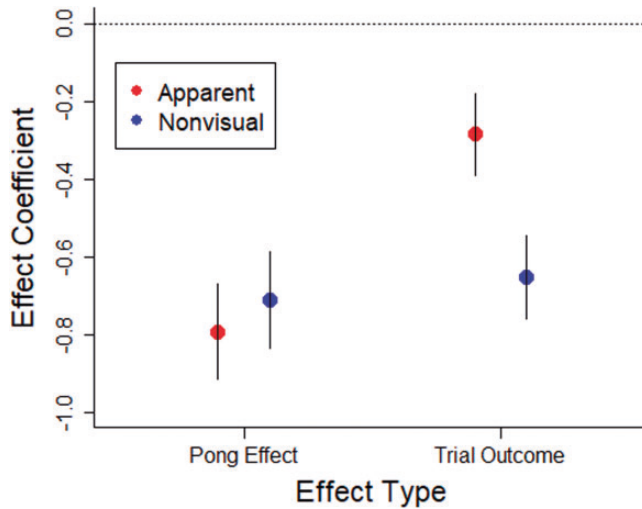


Figure 3. The model's coefficient (and standard errors) for each effect type for each instruction condition. The Pong effect refers to the impact of paddle size on estimated speed. Negative coefficients indicate that as paddle size increased, speed judgments decreased. The trial outcome effect refers to the impact of whether the ball was successfully blocked on estimated ball speed. Negative coefficients indicate that for successful trials, participants judged the ball as slower compared with misses. The dashed line at zero indicates no effect.

Note. Please refer to the online version of the article to view the figure in colour.

Before theories accommodate these changes, it is necessary to critically evaluate the claim that these effects reflect genuine differences in perception. If a person's ability to act influenced judgments, rather than perception, the results would have no implications for theories of perception. Differentiating perceptual from nonperceptual effects is challenging because perception cannot be measured directly. One strategy, implemented by Woods et al. (2009) and further highlighted and encouraged by Firestone and Scholl (2016), is to manipulate the instructions given to participants. If an effect is due to judgment-based processes, encouraging participants to take into account nonvisual factors will enhance the involvement of judgment-based processes such as altering perceptual judgments based on how the target feels rather than how it looks. If an effect is not due to perceptual processes, the effect should be eliminated when participants are specifically told to report how it appears and to ignore nonvisual factors.

Instructing participants to report how the target appears did not eliminate the Pong effect. Furthermore, instructing participants to take into account nonvisual factors when judging ball speed did not increase the Pong effect. This is opposite that predicted by a judgment-based account and consistent with the claim of a perceptual effect.

Importantly, the instruction manipulation effectively altered the judgment-based effect of how trial outcome affected speed estimates. The impact of trial outcome on estimated speed was significantly larger for participants given the nonvisual instructions than for participants given the apparent instructions. This pattern was expected given that the effect of trial outcome is considered a judgment-based effect (Witt et al., 2017; Witt & Sugovic, 2012). Thus, this analysis served as a manipulation check to ensure that the instructions effectively altered responses.

Summary

Can a person's ability to act influence what they see? The present experiment was critical because the claim that the ease to block a ball influences *perceived* speed requires systematically examining and ruling out *all* possible alternative explanations. While much research has been devoted to this Herculean task (Witt, 2017), prior work on the Pong effect had neglected manipulation of instructions, one of the primary recommendations by critics (Firestone & Scholl, 2016; Woods et al., 2009). The current research closes this critical gap. The Pong effect has now been run through the gauntlet and passed every proposed test of alternative explanations. The evidence shows that a person's ability to act can influence spatial perception.

Authors' Note

Stimuli, data, analysis scripts, and supplementary materials can be found at <https://osf.io/b6dwr/>.

Declaration of Conflicting Interests

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ORCID iD

Jessica K. Witt  <https://orcid.org/0000-0003-1139-1599>

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