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Kicking to bigger uprights: Field goal kicking performance influences perceived size

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Abstract. Perception relates not only to the optical information from the environment but also to the perceiver's performance on a given task. We present evidence that the perceived height and width of an American-football field goal post relates to the perceiver's kicking performance. Participants who made more successful kicks perceived the field goal posts to be farther apart and perceived the crossbar to be closer to the ground compared with participants who made fewer kicks. Interestingly, the current results show perceptual effects related to performance only after kicking the football but not before kicking. We also found that the types of performance errors influenced specific aspects of perception. The more kicks that were missed left or right of the target, the narrower the field goal posts looked. The more kicks that were missed short of the target, the taller the field goal crossbar looked. These results demonstrate that performance is a factor in size perception.

1 Introduction

Anecdotally, many athletes claim to perceive their sport-specific targets as bigger on days that they perform better. For example, baseball players in the midst of a hitting spree say the ball looks as big as a grapefruit. Golfers dropping birdie after birdie relate the size of the cup to a bucket. In contrast, on bad days, athletes claim that they are swinging at aspirins or putting to the inside of a doughnut. Recent empirical research suggests these experiences are not just hyperbole, but reflect a psychological reality. Judgments of the size of a softball are correlated with batting performance (Witt and Proffitt 2005), and judgments of golf hole size are correlated with golf performance (Witt et al 2008). These results suggest that an athlete's performance does, in fact, influence perception of the size of the target.

Many factors contribute to an individual's perception of size, with the most important information coming from optical cues. However, most theories of size perception would contend that action-related factors such as performance should not influence perception. Given the radical nature of the claim that performance influences perception, several alternative hypotheses must be considered. One alternative is that performance influences one's memory of the target but not the person's actual perception of the target. Indeed, in previous studies on softball players and golfers target size was measured after the sport had concluded, so the target was no longer within view. A second alternative is that previous effects may be due to pre-existing differences in perception prior to performance. For example, a softball player could initially perceive the ball as bigger, and this exaggerated perception may coincide with better hitting performance. As such, there could be a positive correlation between performance and perception without conceding the claim that performance influences perception. Here we aim to address both of these alternatives. We measured the perceived size of a target that remained in view both before and after performing an American-football kicking task. Results indicate that performance does influence perception.

The claim that performance influences perception is grounded in a growing body of research that demonstrates effects of action on perception. As discussed above, sport performance influences perception as has been documented in softball players

(Witt and Proffitt 2005) and golfers (Witt et al 2008). Action-specific perceptual effects also occur in other aspects of spatial perception such as distance and slant. For instance, targets that are just beyond arm's reach look closer when the perceivers intend to reach with a tool than when they intend to reach without the tool (Witt et al 2005; Witt and Proffitt 2008), and hills look steeper to participants wearing a heavy backpack or those who are fatigued after a long run (Bhalla and Proffitt 1999). In these studies and others (see section 4), the optical information is constant, yet perception is influenced by the perceiver's ability to perform the action.

The effects of action on perception go beyond spatial perception. Perceived speed of point-light walkers was less precise when participants viewed the displays while walking on a treadmill compared with participants who stood still or rode a stationary bike (Jacobs and Shiffrar 2005). That is, the perceivers' own actions influenced their perceptual sensitivity to the motion of others. Similarly, when viewing alternating images of two body postures, participants perceived the movement path of the body as following biomechanical limitations rather than as following a shorter, but physically impossible path (Shiffrar and Freyd 1990). Concurrent actions help to resolve the ambiguity in bistable motion by biasing the perceived motion in the same direction as the perceiver's own motion (Wohlschlager 2000). Similarly, concurrent actions also resolve ambiguity in auditory perception. Ambiguous scales are perceived to be ascending when the perceiver's movement on a piano would result in ascending tones (Repp and Knoblich 2007). Taken together, this growing body of evidence demonstrates that action influences perception.

Action can influence perception in a number of ways. First, action can change the sensitivity of the percept, as in the case of perceived speed of point-light walkers (Jacobs and Shiffrar 2005). Action can also bias perception in an ambiguous setting, such as in the case of the studies just described. However, in the current investigation, we examined a third way in which action can influence perception. Specifically, action can bias the perceived size of objects, even when presented in a full-cue environment.

In order to strengthen the evidence for this claim, we aim to demonstrate that performance influences perception, rather than a memory of the target, and that the effects cannot be accounted for by pre-existing differences in perception prior to performing the task. In previous experiments on softball players and golfers Witt and colleagues (Witt and Proffitt 2005; Witt et al 2008) measured perceived target size when the softball and golf hole were not in view. However, follow-up laboratory studies suggest the effect is perceptual rather than one of memory. Participants putted from a location near the hole, so making the putts was relatively easy, or they putted from a location far from the hole, where putting was much more difficult. Subsequently, participants estimated hole size while viewing the hole from a neutral location so as to minimize any size – distance confounds (see Witt et al 2008 for further discussion on this issue). Participants in the easy condition perceived the hole to be larger compared with participants in the difficult condition (Witt et al 2008). Other evidence that performance can influence perception comes from another laboratory task in which participants had to drop a miniature dart onto a target. Participants who required fewer drops to hit the target perceived the target to be bigger (Wesp et al 2004). Because participants viewed the target while making their estimates as well, these findings support the notion that performance influences perception, rather than memory.

Another alternative for the claim that performance influences perception is that pre-existing differences in size perception may account for our findings. People could initially perceive a target as larger. This initial perception could coincide or even be a catalyst for better performance. As a result, although there would still be a positive correlation between performance and perception, it would seem unlikely that performance influenced perception. None of the previous research measured perception before and after performing the task. If the correlation between performance and perception is due to pre-existing differences, then these differences should be apparent prior to performing the task as well as afterwards. In contrast, if only post-performance perceptions are correlated with performance, this result suggests that performance actually influences perception.

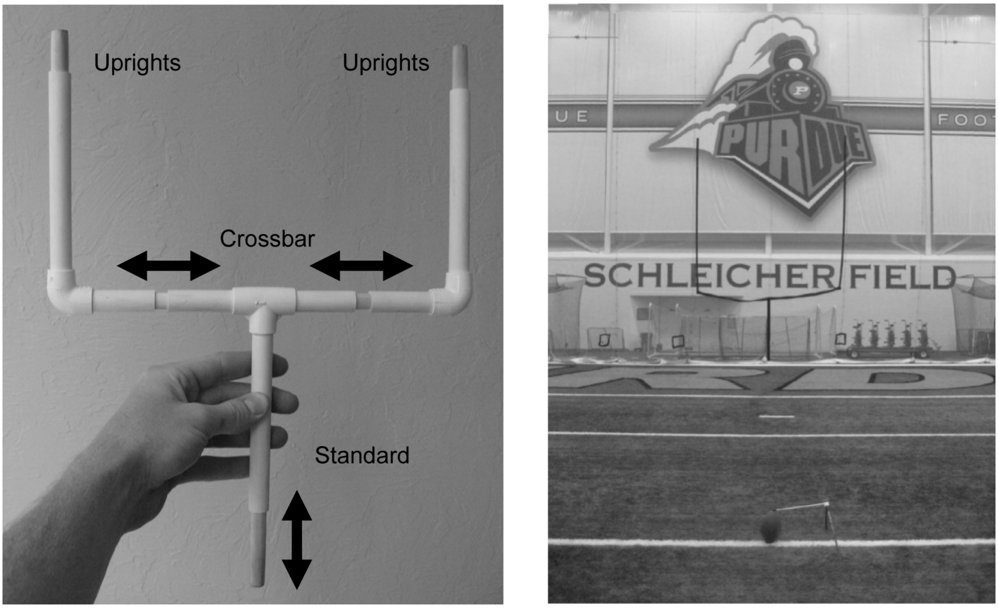
2 Method

2.1 *Participants*

Twenty-three volunteers (thirteen female, ten male; mean age = 30.22 years) from the West Lafayette, Indiana community agreed to participate. All gave informed consent. All but one participant had previous experience with sports; however, only one participant had any experience with kicking field goals.

2.2 *Apparatus and stimuli*

The study was completed in an indoor football practice facility, so factors such as wind (none), temperature (21 °C), lighting (artificial white), and field conditions (FieldTurf® synthetic) remained constant across participants. The indoor facility did not have a field goal post, but rather had a white nylon net, which hung from the ceiling over the end line of the endzone and stretched the width of the football field (48.77 m). Black Velcro®, that was the same width as regulation steel posts (15.24 cm) and corresponded to the dimensions of regulation field goal posts (see below), was placed on the net (see figure 1). During the test phase, participants were positioned on the 10-yard line (18.29 m from the field goal posts) in the middle of the field. During the practice phase, participants were positioned to the far right side and only approximately 0.5 m from the net, so that when they practiced kicking they got no visual feedback as to the outcome of each kick.



(a) (b)

Figure 1. (a) The mock uprights used to make size judgments. Participants could adjust the width between the uprights by shortening or lengthening the crossbar, and the height of the crossbar by lengthening or shortening the standard on the apparatus. Arrows indicate where adjustments could be made. (b) Location where the experiment took place. The football tee is holding a ball in place for the kicker.

An adjustable field goal post was created with PVC pipe that was 2.54 cm in diameter (see figure 1). The vertical pipes (referred to as 'uprights') were built to slide in and out along the width of the horizontal pipe ('crossbar'). This allowed for adjustment in the overall width of the mock uprights. The single vertical pipe below the crossbar ('standard') also extended up and down. This allowed for adjustment in the height of the mock crossbar. The width between the mock uprights ranged from 23.66 cm to 44.45 cm. The height of the crossbar ranged from 14.92 cm to 30.16 cm. Therefore, in allowing for both horizontal and vertical expansion and contraction, the proportion (ie ratio of upright width to crossbar height) of the mock field goal posts could be changed from 2.5 : 1 to 1 : 1.5. The ratio of regulation field goal posts is 1.85 : 1 (5.64 m : 3.05 m).

2.3 *Procedure*

Participants were run individually. During the warm-up phase, participants were given three footballs and a football kickoff tee, which held the football upright while they kicked it. Participants warmed up by kicking directly into the net positioned approximately 0.5 m away. Participants kicked from a position close to the net so that they would not receive any visual feedback on their ability to kick successfully. After 3 – 5 min of individual practice, participants came to the 10-yard line in the middle of the field. This location, where all tasks would be completed, is where point after touchdown tries are attempted at most levels of American football. Including the end zone, participants were 18.29 m from the field goal posts.

Participants were first asked to estimate how many kicks out of 10 they thought they would make. Next, using the mock field goal posts, participants were asked to create a to-scale version of the actual field goal posts. The dimensions of the mock field goal post apparatus were always set at the maximum values before giving it to the participant. Participants were not informed of the actual dimensions of American-football field goal posts. However, participants faced the actual field goal posts while making their adjustments and therefore had access to visual information about the size of the field goal throughout their adjustments. Two critical values were recorded from participants' adjustment of the apparatus: (i) width of the uprights (ie distance between the inside of the left upright and the inside of the right upright) and (ii) height of the crossbar (ie length of the standard, from its bottom to its intersection with the crossbar).

Following this pre-kicking estimation, participants kicked 10 field goals. Results of participant attempts were recorded on a grid. This was done by writing the number of the corresponding kick (1, 2, 3, ...) on the grid where the participant's kick crossed the vertical plane of the field goal posts. This allowed for the recording of not only whether participants missed the field goal, but how they missed it as well (ie too short or too wide). Immediately following their final kick, participants were asked to estimate the height and width of the field goal posts using the same apparatus. The dimensions of the apparatus were again set at their maximum values before giving it to the participant so that each participant would have to set the dimensions based on his/her current perception of the actual field goal rather than simply adjusting the pre-kicking judgments. As with the pre-kicking estimate, participants faced the actual goal posts while making their adjustments.

3 Results

As shown in figure 2, participants who made more successful kicks perceived the goal to be bigger compared with participants who made fewer successful kicks. A successful kick was defined as the ball contacting the net between the uprights and above the crossbar. We performed a median split on the data based on how many kicks were successful

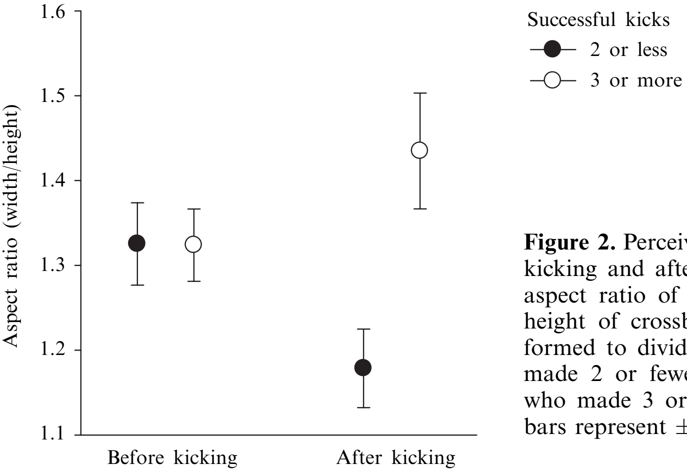


Figure 2. Perceived size of the field goal before kicking and after kicking as calculated as an aspect ratio of width of uprights divided by height of crossbar. A median split was performed to divide participants into those who made 2 or fewer successful kicks and those who made 3 or more successful kicks. Error bars represent ±1 SE.

(mean = 3.17; median = 2). This resulted in twelve participants with 2 or fewer successful kicks and eleven participants with 3 or more successful kicks. We calculated aspect ratios (perceived width/perceived height) for estimated size both before and after kicking. A repeated-measures ANOVA with time of estimate (pre- and post-kicking) as a within-subjects factor, success group as a between-subjects factor, and aspect ratio as the dependent factor revealed a significant interaction between time of estimate and success group ($F_{1,21} = 14.32$, $p < 0.01$, $\eta^2 = 0.41$). Individual one-way ANOVAs for each time revealed a significant effect for group on post-kicking aspect ratio ($F_{1,21} = 9.94$, $p < 0.01$, $\eta^2 = 0.32$). Participants who made more successful kicks perceived a larger goal than participants who made fewer successful kicks. In contrast, kicking success was not a significant factor in pre-kicking aspect ratio ($F_{1,21} = 0.00$, $p = 0.98$). Furthermore, separate one-way ANOVAs for each group revealed that the less-successful group perceived the goal to be smaller after kicking ($F_{1,11} = 8.71$, $p < 0.05$, $\eta^2 = 0.44$), whereas the more successful group perceived the goal to be bigger after kicking ($F_{1,10} = 5.82$, $p < 0.05$, $\eta^2 = 0.37$).

We also examined perceived height and perceived width as separate measures with a repeated-measures ANOVA with time of estimate (pre- and post-kicking) and perceived dimension (height and width) as within-subjects factors and success group as a between-subjects factor. The key finding was a 3-way interaction between time, dimension, and group ($F_{1,21} = 13.33$, $p = 0.001$, $\eta^2 = 0.39$—see figure 3). While there were no perceptual differences between the two groups before kicking, after kicking the uprights looked wider and the height of the crossbar looked shorter to the group who made more kicks than to the group who made fewer kicks. To confirm, we ran two additional repeated-measures ANOVAs with only the pre-kicking estimates and only the post-kicking estimates. As expected, there was not a significant interaction between success group and perceived dimension in the pre-kicking estimates ($F_{1,21} = 0.01$, $p = 0.91$); however, there was a significant interaction between success group and perceived dimension in the post-kicking estimates ($F_{1,21} = 9.49$, $p < 0.01$, $\eta^2 = 0.31$). The group that had more success at kicking perceived the field goal to be wider and the crossbar to be shorter after performing the kicking tasks compared with the group that had less success at kicking.

3.1 *Kicking success*

In addition to dividing participants on the basis of a median split, we also looked at the correlations between performance and perception. As predicted, kicking success was significantly correlated with post-kicking aspect ratios ($r_{21} = 0.56$, $p < 0.01$, always one-tailed—see figure 4). Kicking success did not significantly correlate with pre-kicking

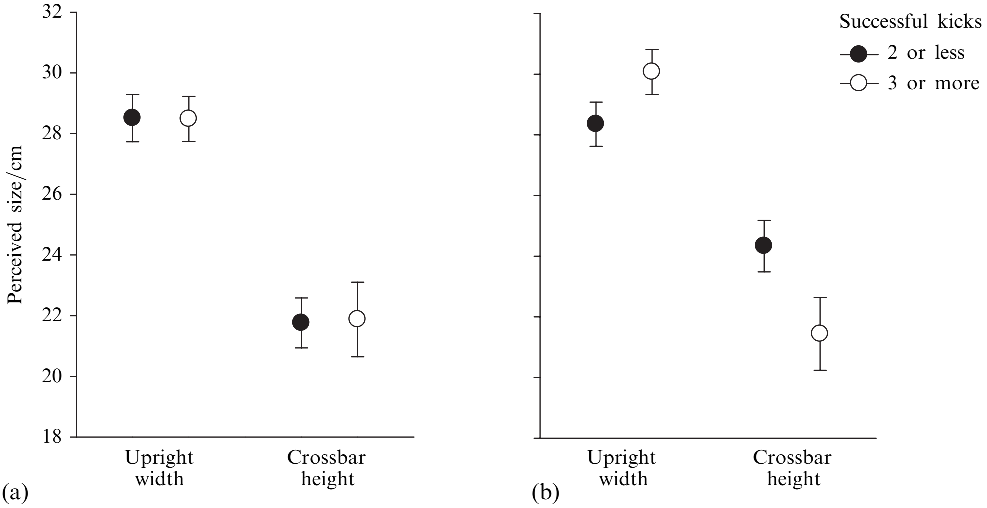


Figure 3. Perceived width of uprights and height of crossbar (a) before kicking and (b) after kicking. A median split was performed to divide participants into those who made 2 or fewer successful kicks and those who made 3 or more successful kicks. Error bars represent ±1 SE.

aspect ratios ($r_{21} = 0.06$, $p = 0.78$). The more success one had at kicking the ball through the field goal, the larger the goal appeared to be after kicking.

This pattern of results was apparent in both dimensions. There was a significant negative correlation between number of successful kicks and perceived height of the crossbar after kicking ($r_{21} = -0.39$, $p < 0.05$—see figures 5a and 5b). A marginally significant correlation also emerged between number of successful kicks and perceived width of the uprights ($r_{21} = 0.33$, $p = 0.06$). However, after accounting for participants' perceptual estimates before kicking, significant effects were noted for perceptions of both crossbar height and upright width.

We used two methods to account for perceptual differences before kicking: difference scores and partial correlations. Difference scores were computed for each dimension by subtracting pre-kicking size estimates from post-kicking size estimates. We found a

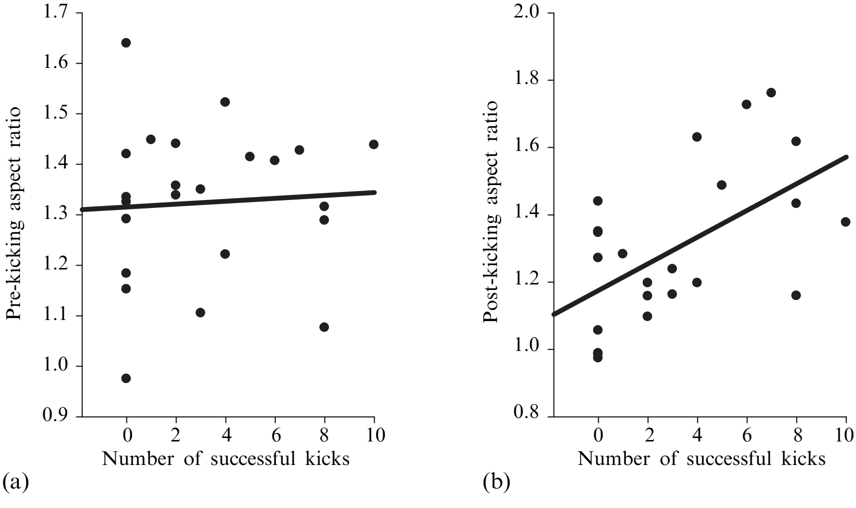


Figure 4. Perceived size of the field goal (measured as an aspect ratio of perceived width/perceived height) as a function of number of successful kicks (a) before kicking, and (b) after kicking. Each circle represents the data of one or more participants. Lines represent linear regression.

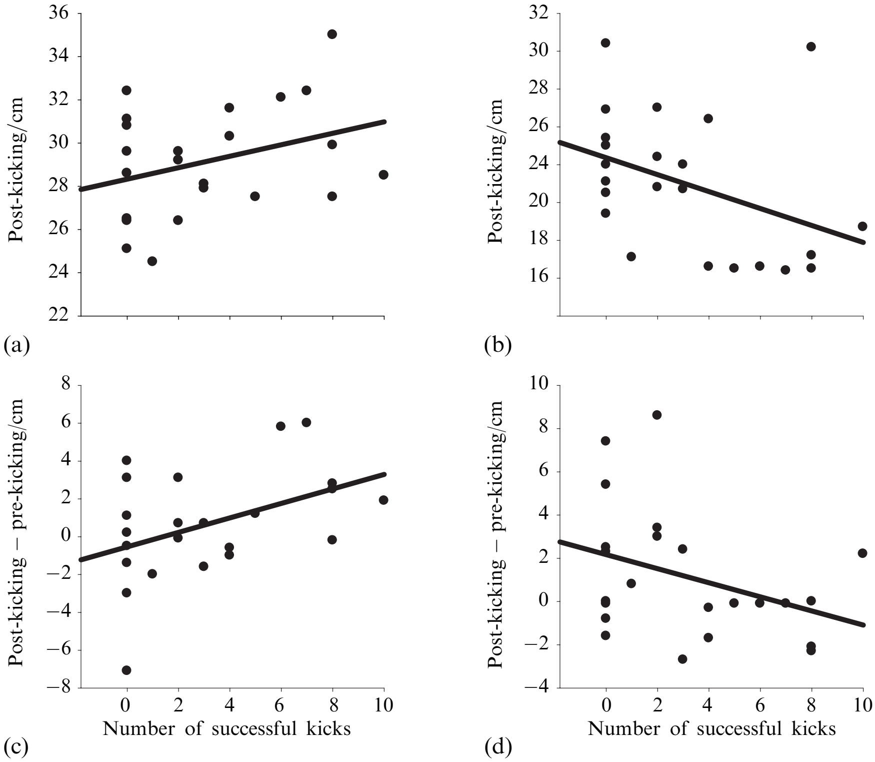


Figure 5. [(a) and (c)] Perceived width of uprights and [(b) and (d)] perceived height of crossbar as a function of number of successful kicks: (a) and (b) show perceived estimates after kicking; (c) and (d) show difference scores of perceptual estimates after kicking – estimates before kicking. Each circle represents the data of one or more participants. Lines represent linear regression.

significant correlation between the number of successful kicks and difference in perceived crossbar height ($r_{21} = -0.36$, $p < 0.05$) and between the number of successful kicks and difference in perceived upright width ($r_{21} = 0.43$, $p < 0.05$—see figures 5c and 5d).

Partial correlations controlling for pre-kicking estimates revealed the same pattern of results. We found a significant partial correlation between the number of successful kicks and post-kicking perceived crossbar height after controlling for pre-kicking perceived crossbar height estimates ($pr_{21} = -0.42$, $p < 0.05$). We found a significant partial correlation between the number of successful kicks and post-kicking perceived upright width after controlling for pre-kicking perceived upright width estimates ($pr_{21} = 0.42$, $p < 0.05$). In sum, the more kicks the participants made successfully, the shorter their perception of crossbar height and the wider their perception of the uprights.

No significant correlations emerged between any of the pre-kicking perceptual judgments and participants' rate of success (see figure 6). Pre-kicking perceived upright width was not significantly correlated with number of successful kicks ($r_{21} = -0.15$, $p > 0.24$), nor was success significantly correlated with perceived crossbar height prior to kicking ($r_{21} = -0.12$, $p > 0.29$). Thus, the results of the current investigation cannot be accounted for by participants' perceptual differences prior to kicking. Importantly, it seems that the actual experience of kicking, along with its success or failure, influences perception, rather than a different perception leading to better success.

3.2 *Types of failures*

We also examined the relationship between perception and how participants missed. Misses were categorized into kicks that were too short (mean = 6.09, minimum = 0,

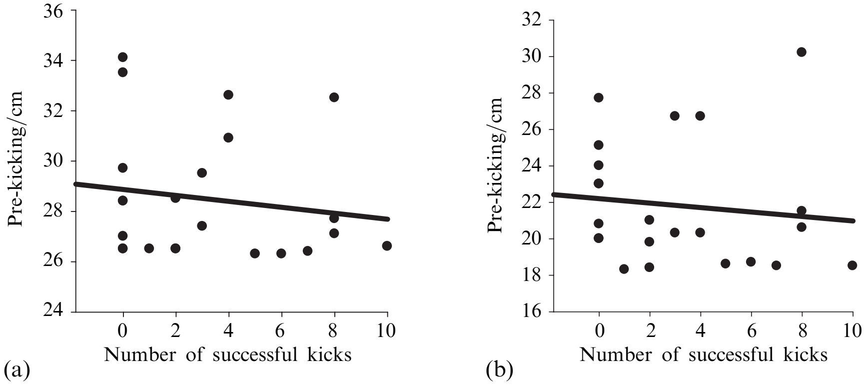


Figure 6. (a) Perceived width of uprights and (b) height of crossbar before kicking as a function of number of successful kicks. Lines represent linear regression.

maximum = 10; SD = 3.55) or too wide (mean = 2.39, minimum = 0, maximum = 6; SD = 1.67). The correlation between total misses wide and participants' difference score for upright width (ie participants' perceptions of the width of the uprights after kicking minus participants' perceptions of their width before kicking) was significant ($r_{21} = -0.37$, $p < 0.05$—see figure 7). That is, participants who more frequently missed the field goal by kicking the ball too wide perceived the uprights to be narrower. Number of kicks missed wide did not significantly correlate with perceived height differences of the crossbar ($r_{21} = -0.15$, $p = 0.25$).

The correlation between unsuccessful kicks that were too short and participants' difference score for crossbar height (ie participants' perceptions of the height of the crossbar after kicking minus participants' perceptions of their height before kicking) was also significant ($r_{21} = 0.42$, $p < 0.05$—see figure 7). Participants who missed more kicks because they did not kick the ball high enough perceived the crossbar as being higher. Number of kicks missed short also correlated with differences in perceived width of the uprights ($r_{21} = -0.45$, $p < 0.05$). We are unsure why missing kicks in one dimension relates to perception of the other dimension. However, the categories of missed kicks were not exclusive, so several of the kicks that were missed short were also missed wide, which could account for why perceived width was also affected.

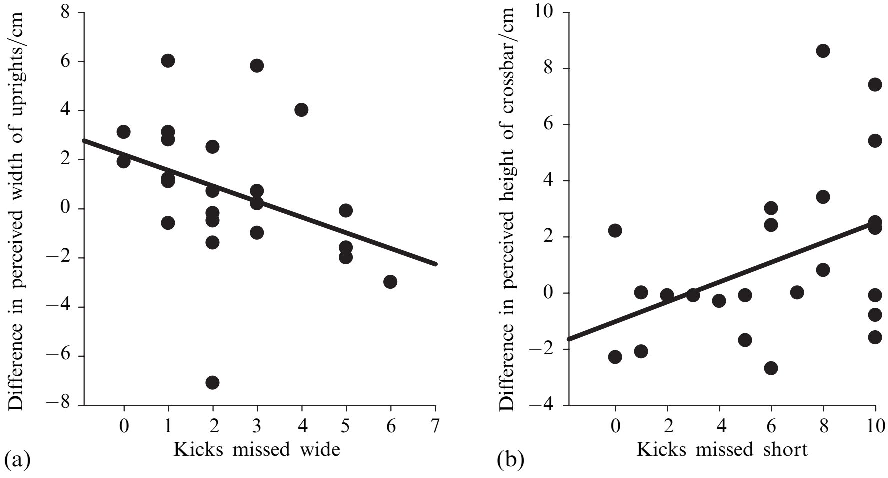


Figure 7. (a) Perceived width of uprights after kicking minus that before kicking as a function of number of kicks missed wide. (b) Perceived height of crossbar after kicking minus that before kicking as a function of number of kicks missed short. Lines represent linear regression.

When we examined kicks that were only short but not also wide, we found a significant correlation with differences in perceived height ($r_{21} = 0.48$, $p = 0.01$), but not a significant correlation with differences in perceived width ($r_{21} = -0.31$, $p = 0.15$). These data suggest that how the target is missed relates to how the target is perceived.

3.3 *Predicted success*

We also examined whether there was a relationship between perceived field goal post size and participants' predictions of how they would do. One might expect field goal posts to look larger prior to kicking for participants who predicted making more successful kicks. However, predicted success was not significantly correlated with pre-kicking aspect ratio ($r_{21} = 0.05$, $p > 0.81$). The correlations between predicted success and pre-kicking estimates of separate dimensions (height and width) were also not significant (rs > -0.17, ps > 0.22—see figures 8a and 8c).

Participants in the current investigation actually made more kicks (mean = 3.17, SD = 3.26) than they predicted (mean = 3.09, SD = 2.86). Prediction error (mean = 0.09, minimum = −4, maximum = 6; SD = 2.23) was calculated by computing the difference between a participant's number of successful kicks minus his/her prediction.

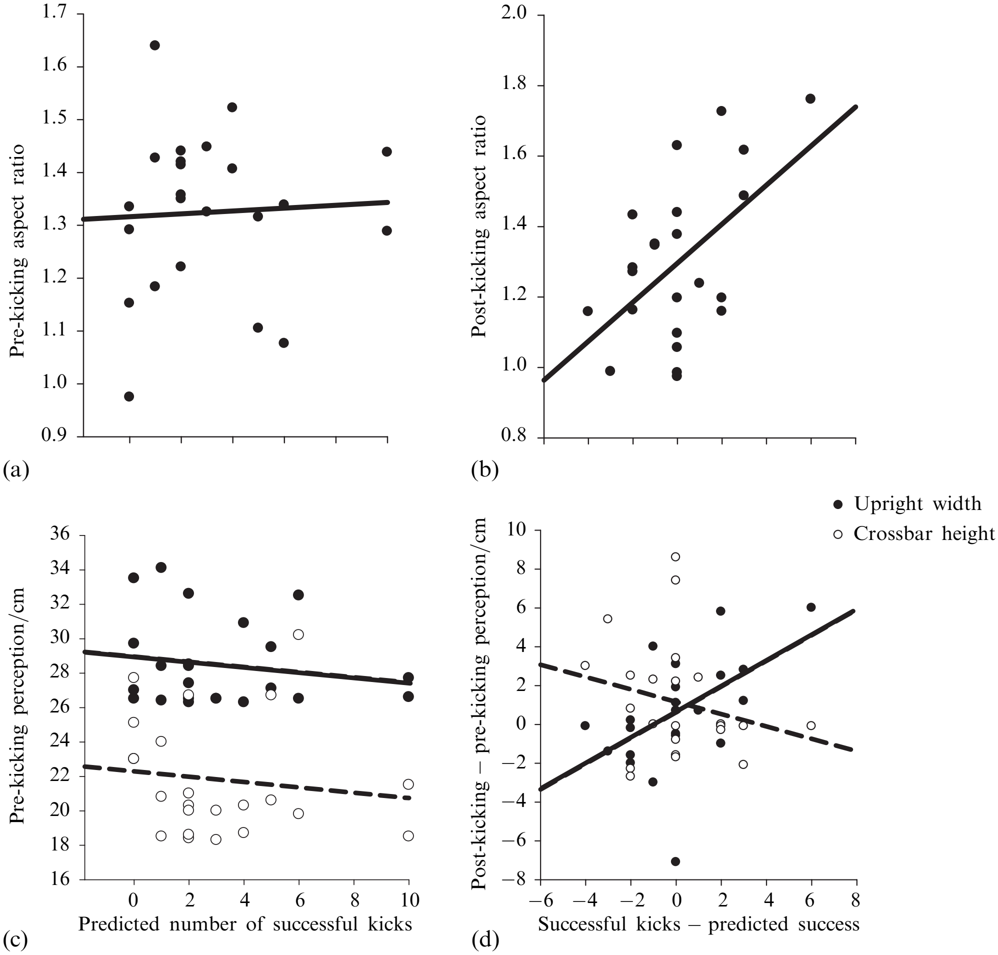


Figure 8. Perceived goal size [(a) and (b) aspect ratio; (c) and (d) width and height separately] as a function of prediction success. Perceived goal size [(a) and (b) aspect ratio; (c) and (d) differences between post-kicking and pre-kicking estimates for width and height separately] as a function of the difference between number of successful kicks minus predicted number of successful kicks. Lines represent linear regression.

Prediction error significantly correlated with post-kicking aspect ratio ($r_{21} = 0.54$, $p < 0.01$—see figure 8d). The correlation between prediction accuracy and participants' perceived differences in upright width was significant ($r_{21} = 0.51$, $p < 0.01$). The more kicks made than predicted, the wider the uprights looked after kicking (see figure 8d). However, prediction error did not significantly correlate with difference in perceived crossbar height ($r_{21} = -0.24$, $p = 0.14$—see figure 8d).

4 Discussion

Field goal kicking performance influenced perceived size of the field goal posts. The uprights looked farther apart and the crossbar looked lower to people who made more successful kicks, demonstrating a relationship between performance and perception. Although perceived size is mainly a factor of optical information, which was available at the time that participants made their estimates, perceived size is also influenced by the perceiver's performance on a given task.

The current investigation expands on previous research in a number of ways. In previous studies of golfers (Witt et al 2008) and softball players (Witt and Proffitt 2005) the target was always relatively small and participants had manual experience with the object. Softball players regularly hold and throw a softball in addition to hitting it. Golfers reach into the cup to retrieve their ball on every hole. In contrast, field goal posts are large and few individuals would have reason to gain any manual experience of them. Thus, the average person's entire experience of field goal posts is visual. Interestingly, the correlations in the current investigation were somewhat larger than correlations between perception and performance in the previous studies, which were around 0.30. Thus, perhaps manual experience with a target might help to reduce the bias of performance on target-size perception.

An important advancement made by the current study involves the use of pre-kicking perceptual judgments. In previous studies judgments of perceived size have been obtained only after sport participation. Thus, it was not clear whether people performed better and subsequently perceived the target as larger, as Witt and colleagues (2005, 2008) have previously claimed. An alternative is that pre-existing perceptual differences were present that either coincided with or perhaps even facilitated better performance. According to this alternative, the significant correlation between performance and perception would not be due to a causal effect of performance on perception. In the current investigation, we found no evidence for pre-existing perceptual differences. Pre-kicking estimates were not significantly correlated with measures of performance. In contrast, post-kicking estimates did significantly correlate with kicking performance. Given the absence of significant correlations with pre-kicking estimates, this result provides strong evidence that performance actually influences perception of size.

Furthermore, the current results also demonstrate that the effect is driven by perception rather than memory. Participants viewed the field goal posts while making their estimates by adjusting the mock field goal apparatus, yet we still found an effect of performance. In the softball (Witt and Proffitt 2005) and golf (Witt et al 2008) experiments, targets were out of view when athletes made their post-performance judgments. In the current experiment, participants viewed the target throughout the experiment and while making both pre- and post-performance size estimates. Therefore, the current results suggest an effect on perception rather than memory (see also Wesp et al 2004; Witt et al 2008).

Given these advancements, we believe the current results demonstrate an effect of performance on perception. Many researchers are resistant to such a claim. Traditionally, perception has been considered to be a function mainly of optical information and independent of action and intention. Proponents of this account attempt to explain results demonstrating an effect of performance on perception by claiming the effect is due to a type of response bias (Loomis and Philbeck 2008).

The current results provide support for the view that the effects are not due to a response bias. Participants predicted how many kicks they thought they would make before estimating field goal size. If our results were due to a response bias, we would expect that predictions would also correlate with perceived size. Participants who thought they would make more kicks should have adjusted their responses to indicate a larger field goal. In contrast, we found that predicted success did not significantly correlate with pre-kicking estimates. Such evidence is counter to what would be expected if these results were due to a response bias.

However, an interesting question that remains is whether a predictive effect would emerge in expert kickers. Skilled athletes may have an initial expectation or sense of how well they will perform. Unlike novices, this expectation might more closely match their upcoming performance. If so, then perhaps this expectation could influence perceived size even before the experts attempt to kick the ball. Given that perception is about anticipated action (Witt et al 2004, 2005), one might expect such a result in experts who can anticipate future performance.

Another interesting finding in the current experiment reveals that the manner in which participants missed kicks related to how they perceived the field goal posts. Participants who missed their kicks wide perceived the uprights as narrower. Similarly, participants who missed their kicks short, perceived the crossbar as higher off the ground. This result demonstrates a level of specificity, namely that perceptual effects occur according to where performance excels and where inadequacies exist.

Our proposal of a relationship between perception and action is preceded by several theories on and experiments demonstrating a perception – action link. Notably, Gibson (1979) proposed that perceiving the environment in terms of its affordances, which are the possibilities for action, is a fundamental, and even primary, part of perception. In line with this claim, research demonstrates that the perceptual system is highly tuned to the boundaries at which actions are and are not possible (eg Mark 1987; Mark et al 1999; Warren 1984; Warren and Whang 1987).

Other experiments have demonstrated that intention to act influences perception. For example, when reproducing a design from a model, participants looked back and forth between the model for specific information such as color or shape. When looking for the specific shape, participants were less likely to notice an unexpected change in color (Ballard et al 1997). Ballard et al interpret this result as evidence that perception is actively seeking information from the environment depending on the perceiver's needs and intentions, rather than passively receiving information. This claim resonates with recent proposals of embodied cognition that cognitive processes should be considered in the context of having a body that operates in the environment (eg Barsalou 2008; Clark 1998; Wilson 2002). Intention also influences performance in visual-search tasks: when searching for a target amongst similarly oriented objects and similarly colored objects, participants made fewer initial saccades to objects of an incorrect orientation when intending to grasp than when intending to point (Bekkering and Neggers 2002). Also, intention to grasp a disc surrounded by smaller or larger circles, a task that is immune to visual illusions (eg Aglioti et al 1995; but see also Franz 2001), reduced the perceptual size of the Ebbinghaus illusion (Vishton et al 2007). In addition, concurrent and recently performed actions also influence perception. Lateral movements led to reduced visual sensitivity of an arrow pointed in the same direction as the movement compared with an arrow pointing the opposite way (eg Musseler and Hommel 1997). This result provides support for the claim that there is a level of representation at which perception and action are coded as the same (Hommel et al 2001).

As mentioned before, effects of performance on perception have been demonstrated in softball players (Witt and Proffitt 2005) and golfers (Witt et al 2008). These effects are consistent with previous research showing the influence of ability on perception.

When reaching abilities are extended by the use of a tool, targets that are presented beyond reach of the arm look closer when the perceiver intends to reach with the tool (Witt et al 2005; Witt and Proffitt 2008). These experiments are also consistent with studies showing effects of effort on perception. When more effort is required to perform an intended action, the target is perceived differently. For example, when walking to a target requires more effort, the targets look farther away (Proffitt et al 2003; Stefanucci et al 2005; Witt et al 2004). Similarly, targets also look farther away when the effort required to throw to the targets increases (Witt et al 2004). Tools oriented so that they are more difficult to grasp look farther away than when they are oriented to be easier to grasp (Linkenauger et al, in press). In addition, chronic-pain patients who experienced pain when walking to a target perceived the targets to be farther away than controls (Witt et al 2009). Perception of hill slant is also influenced by effort: hills look steeper when the perceiver wears a heavy backpack or is fatigued (Bhalla and Proffitt 1999; Proffitt et al 1995).

The common thread through these studies is that action modulates perception. Thus, perception is not just a reconstruction of the geometry of the environment but includes a bias specific to the perceiver's abilities, energetic potential, and intentions. Previously, Proffitt (2006) claimed an evolutionary advantage for the effects of energetic potential on perception. Specifically, because energy conservation is so important for survival, it is useful to perceive the environment in terms of the energetic costs associated with acting. For example, by perceiving a hill as steeper when fatigued, the perceiver can plan to walk at a slower pace, thus conserving energy.

The effect of performance on perception is likely to also have adaptive effects. For instance, an athlete confronted with a larger target can relax and simply aim for the target without needing to exert additional resources to accomplish the goal. In contrast, when an athlete has to act on a smaller target, the athlete must exert more resources and focus more attention in order to accomplish the goal. Such an adjustment would be beneficial when the athlete is not playing well (which was the reason the target looked smaller). Therefore, seeing the same target as bigger or smaller could potentially assist in preparation to act on the target.

In summary, we demonstrated that kicking performance influenced the perceived size of American-football field goal posts. Participants who made more successful kicks perceived the goal to be larger than those who made fewer successful kicks. The field goal posts were in view while participants made their estimates, suggesting that the effect is perceptual rather than one of memory. Furthermore, we found no significant correlations on perceived size prior to kicking, which rules out any accounts based on pre-existing differences in our participants. Significant perceptual effects only emerged after participants had attempted to make 10 field goals. Such a result provides further evidence that performance does in fact influence size perception.

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