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Size estimates remain stable in the face of differences in performance outcome variability in an aiming task

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ABSTRACT

In perceptual-motor tasks such as dart throwing, those who hit the target more successfully report the target to be bigger than those who hit less successfully. While initial evidence seemed to support the recent contention that the variability in performance (rather than the amount of successful hits) may scale reported target size, here we provide counterevidence for this hypothesis. We systematically manipulated performance outcomes in a shuffling task by means of magnetic fields. Participants were asked to slide a disk on a wooden board towards a circular target. Using a within-subjects design, in two conditions throw outcomes were manipulated to produce either high or low variability in performance outcome, while the mean success of performance (i.e., the mean error) remained constant across conditions. Despite the successful manipulations of high and low variability in the performance outcomes, results revealed that size estimates of the target remained stable.

1. Introduction

Theories of embodied perception state that visual perception is not only driven by optical information, but is critically determined by the interaction between the observer and the environment (Proffitt, 2006). It is argued that visual perception emerges and adapts as a function of action capabilities, action intentions, and affordances. Support for this embodied account of perception is given by, for example, research that examined the relationship between the performance of skills that involved aiming at or intercepting a target and size estimates of the those targets (Cañal-Bruland & van der Kamp, 2009; Gray, 2013; Wesp, Cichello, Gracia, & Davis, 2004). Repeatedly, studies have found that better performances are associated with bigger size estimates of task-relevant targets in several tasks such as baseball batting (Witt & Proffitt, 2005), golf putting (Cañal-Bruland, Zhu, van der Kamp, & Masters, 2011; Witt, Linkenauger, Bakdash, & Proffitt, 2008) and field goal kicking (Witt & Dorsch, 2009). For instance, after having had finished a softball game, players were asked to estimate the size of the ball using a visual matching procedure (Witt & Proffitt, 2005), and those with higher batting averages estimated the ball to be bigger than their less successful counterparts. These and similar experiments seem to demonstrate that action-related factors such as performance outcomes relate to reported judgments of the target object's size. While evidence for this

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phenomenon, often referred to as action-specific perception (Witt, 2011; Witt & Proffitt, 2008) seems to abound (for a recent overview, see Gray, 2014), recent research calls into question whether it is indeed perception that is modulated by performance. For example, Cooper, Sterling, Bacon, and Bridgeman (2012) duly pointed out that the vast majority of studies have actually measured memory for a perceived size rather than perception. In an intriguing set of experiments they provided evidence that the effects only occurred when the target was not visible to the observers when making the size estimate. Acknowledging this important finding, we – throughout the manuscript – opt to refer to ‘reported size’ and ‘size estimates’ rather than ‘perceived size’.

Recently, Proffitt and Linkenauger (2013) submitted a novel explanation for action-specific influences on reported size, namely that rather than the mean success (e.g., mean number of successful hits of the hole in golf putting), variability in performance outcome may account for the relationship between performance and reported size of the respective target. In particular, it was argued that the variability in performance outcome represents the capability of a person and hence may provide an individual scaling metric for visual estimates of the target’s size. Consequently, size estimates of the target should vary as a function of a person’s current performance outcome variability. Imagine two golfers that both need ten putts to hole. While the performance success would be identical, the balls’ trajectories and final positions may be very differently distributed around the hole such that for one golfer the balls tend to end up rather farther from the hole whereas for the other (more skilled) golfer the balls would end up consistently close to the hole. According to Proffitt and Linkenauger’s (2013) proposal, the latter golfer with the smaller distribution around the hole should report the hole as being bigger.

Initial evidence supporting this contention came from a re-analysis of a dart-throwing experiment (Cañal-Bruland, Pijpers, & Oudejans, 2012). In fact, results revealed that the participants’ distributions of darts around the target (i.e., dart-throwing outcome variability) were a better predictor for the estimated size of the target than the mean outcome errors (i.e., performance mean radial error). However, while Cañal-Bruland et al. (2012) interpreted their findings as initial support for Proffitt and Linkenauger’s hypothesis (2013), it should be noted that they did not experimentally dissociate outcome variability from performance success (i.e., mean errors). Because the mean error and the variability in performance outcome were not examined independently of each other, the exclusive contribution of performance outcome variability on reported size of the target was not and could not be determined. It logically follows that the question whether performance outcome variability is actually used as a scaling metric of the reported size of the respective target remains unanswered. Therefore, in this study we aimed at scrutinizing Proffitt and Linkenauger’s (2013) hypothesis by examining the independent influence of the variability in performance outcome on size estimates of the target in an aiming task.

To this end, in the current study we manipulated the variability in performance outcome (variable error; VE) in the longitudinal axis through the use of magnets in a target-directed aiming task while maintaining an identical mean error (constant error; CE). In a within-subjects design, participants were asked to slide a disk towards a target on a wooden board (a game in the Netherlands known as ‘shuffling’). Dependent on the distance between the magnet and the target, the disk ended up either further away (resulting in a higher vertical VE; *high-variability condition*) or closer (*low-variability condition*) to the target, while the vertical CEs remained almost identical. Based on Proffitt and Linkenauger’s (2013) proposal, we predicted participants to report the size of the target to be bigger in the low-variability condition when compared to the high-variability condition.

2. Method

2.1. Participants

Forty-two participants (14 male, mean age = 21.4 years [SD = 2.9]) volunteered to take part in the experiment. They were allowed to use their preferred hand for the manual shuffling task (one left-handed) and reported normal or corrected-to-normal vision. All participants provided informed consent prior to experimentation, and the experiment was approved by the ethical committee of the Faculty of Human Movement Sciences, VU University Amsterdam.

2.2. Apparatus

The wooden board was 41 cm in width and 1.61 m in length (see Fig. 1 for a schematic illustration). The board was fixed on a table and a frame so that the playing area was at a height of 78 cm. A gray target with a size of 4 cm in diameter was marked on the shuffleboard. The center of the target was located at the midline (20.5 cm from the side) in a distance of 95 cm from the front of the board and the position of the participant. Participants used the same disk, that is, a circular magnetic disk (0.5 cm in height and 2 cm in diameter) in both conditions.

A magnetic bar underneath the shuffleboard (38.7 cm in width and 15 cm in length) manipulated the outcome of performance. This bar was moved to five different positions by the experimenter. For some of the trials in both conditions the front border of the bar was positioned 2 cm in front of the center of the target to enforce short distances between the target and the disk as well as hits. The use of the other four positions depended on the experimental condition. In the low-variability condition the front border of the bar was moved 6 cm in front of and 2 cm behind the target whereas in the high-variability condition the bar was moved 8 cm in front of and 4 cm behind the target. The experimenter was positioned behind a curtain so that the movements of the bar were not visible to the participants. In addition, participants wore ear protectors to ensure

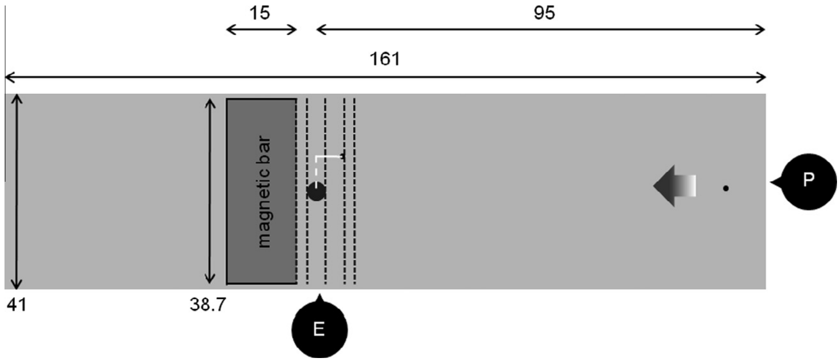

Fig. 1. Schematic illustration of the wooden board. The moveable magnetic bar was invisible to the participants. The experimenter (E) moved the front border of the magnetic bar to one of five different positions (indicated by the dashed black lines) in order to alter the stopping location of the disk. The participants (P) had to slide the disk (indicated by the black dot at the right) to the target (black circle in the middle). The dependent measure was the longitudinal error (i.e., the distance between the center of the target and the center of the disk along the length of the wooden board, as shown by the solid white line). Metrics refer to distances in cm.

that they were not able to hear the switching of the bar. They were told that the ear protectors minimized noise and thus would help them concentrate on the task. The outcome of performance was only manipulated along the longitudinal axis of the board.

A video camera was fixed 1 m above the target to record the distance between the target and the final position of the disk. The width of the board was used as reference for distance measures.

In order to collect size estimates of the target, a projector presented an empty brown sheet of MS PowerPoint on a wall to the right of the participant. The participants drew a gray circle on this sheet with a computer mouse while they kept pushing the *Shift* button on a keyboard (to ensure a circle was generated instead of an ellipse). The mouse, keyboard and projector were positioned on a table between the participants and the wall. The projected target on the wall was at the same distance from the participants as the target on the wooden board (i.e., 95 cm).

2.3. Procedure

Every participant signed an informed consent form before the experimental session started. Afterwards, the participants were instructed that their task was to hit the target circle with the disk as often as possible. A hit was accomplished if the borders of the disk and the target touched. A perfect hit was achieved if the disk ended up centrally on top of the target. The experimenter explained to the participants that the task would be made difficult through an invisible force field that would be acting on the table on most of the trials. The participants could only break through the force field and hit the target if they slid the disc perfectly straight with the perfect speed.[1] In addition, the experimenter advised participants that people typically undershoot the target,[2] thereby encouraging them to avoid undershoots and show their best aiming performance possible. Participants were further instructed to start every trial after the experimenter positioned the disk back on a starting position.

Participants performed 9 practice trials and 40 test trials in each variability condition. During the test trials, the magnetic bar was arranged as follows: the front border of the bar was (i) 2 cm in front of the target in four trials, (ii) 6 cm (low-variability condition) or 8 cm (high-variability condition) in front of the target in 18 trials and (iii) 2 cm (low-variability condition) or 4 cm (high-variability condition) behind the target in 18 trials.[3] The three positions were each used three times during the practice trials. The positions of the magnet behind and in front of the target were used in equal frequency to guarantee a CE close to zero and – most importantly – an almost identical vertical CE in both conditions. The sequence of the magnetic bar's positions was randomized in the practice and in the test phase. The video camera was turned on when the practice trials were accomplished and before the test trials began.

After participants had finished the test trials of one condition, they reported the size of the target using the computer mouse and keyboard. The target was visible during the estimates. Participants were allowed to look back and forth between the monitor and the target on the wooden board as often as they wished while making their size estimate and they were encouraged to adjust their estimate until they were satisfied. Note that indeed while making the judgment, the actual target was not in the visual field of the participant (see Cooper et al., 2012). After a break of 10 min, participants completed the

[1] Pilot work showed that it was impossible to withhold the magnet manipulation from the participants. We therefore decided to provide information about an active force field and introduced the cover story that at the same time aimed to motivate participants to perform at their best on all trials.

[2] Pilot work showed that participants tended to have a higher frequency of undershoots so that the goal of maintaining a near zero vertical CE for both conditions was compromised.

[3] Pilot work indicated that these distances guaranteed success of the variability manipulation, whilst maintaining an almost identical vertical CE.

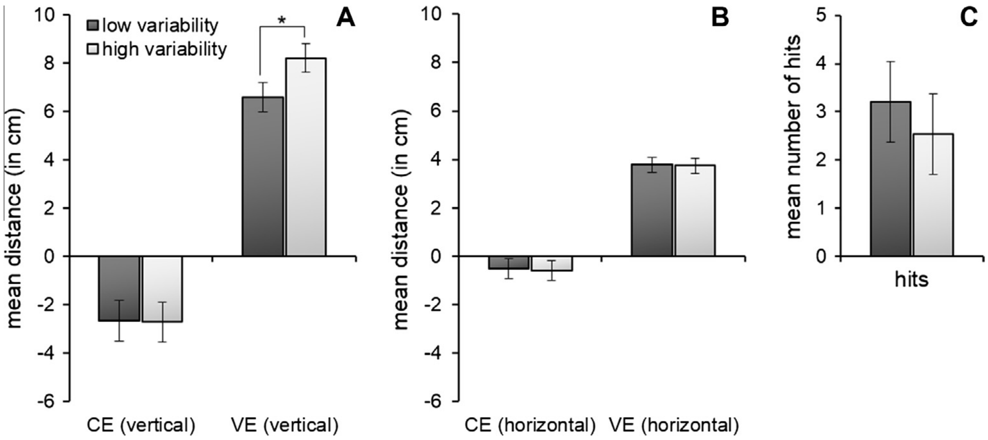

Fig. 2. A. The vertical CE (constant error) and vertical VE (variable error) were computed by averaging the means and the standard deviations, respectively, of the longitudinal distances (in cm) between target and disk for each variability condition. B. The horizontal CE and horizontal VE were computed by averaging the means and the standard deviations, respectively, of the horizontal distances (in cm) between target and disk for each variability condition. C. The number of hits was also averaged over participants for each condition. Error bars represent the 95% confidence interval of the paired differences (Pfister & Janczyk, 2013).

second condition following the same instructions and procedures. During the break they were asked to leave the room to allow the experimenter to prepare the next session. The sequence of conditions was counterbalanced across participants.

Finally, participants filled out a questionnaire about demographical information and answered questions (serving as manipulation checks) concerning the experiment such as whether they generated (correct) hypotheses about the experiment's purpose.

2.4. Data treatment and analyses

Manipulation checks revealed that twelve participants rightfully guessed the aim of the experiment, and hence their data was excluded from further analyses. For the 30 participants that were included in the data analyses, the performance outcome was analyzed based on their individual video records in both variability conditions.[4] Because our manipulation was related to the vertical error (i.e., the *y*-axis), the main dependent measure was the vertical error (in cm), that is, the distance between the center of the target and the center of the disk along the length of the wooden board (see Fig. 1). To rule out that variability in the horizontal errors (i.e., the *x*-axis) may account for potential differences in size estimates, we also analyzed the horizontal errors (in cm). To determine whether the experimental manipulation was successful two two-tailed, paired samples *t*-tests were performed, one comparing the standard deviations of vertical errors (i.e., the vertical VE) in the high- and low-variability conditions and one comparing the mean of the longitudinal errors (i.e., the vertical CE) in the high- and low-variability conditions. The same analyses were repeated for the standard deviations of the horizontal errors (i.e., the horizontal VE) and the mean of the horizontal errors (i.e., the horizontal CE). To assess differences in size estimates between the low- and high-variability conditions, another two-tailed, paired samples *t*-test was calculated. The significance level was set at $\alpha < .05$ and Cohen's d was calculated for effect sizes.

3. Results

3.1. Manipulation check

Results showed that the manipulation of the performance outcome was successful (see Fig. 2). As intended, the vertical VEs were significantly smaller in the low-variability condition than in the high-variability condition, $t(29) = -5.55$, $p < .001$, $d = -1.30$, while there were no significant differences in vertical CEs, $t(29) = 0.13$, $p = .902$, $d = 0.03$, and number of hits, $t(29) = 1.49$, $p = .148$, $d = 0.45$. Results showed further that there were no differences between the high- and low-variability conditions for the horizontal CEs, $t(29) = 0.34$, $p = .736$, $d = 0.06$, and the horizontal VEs, $t(29) = 0.33$, $p = .748$, $d = 0.06$.

3.2. Size estimates

In contrast to the hypothesis, there was no significant difference in size estimates between the two variability conditions (see Fig. 3), $t(29) = -0.24$, $p = .815$, $d = -0.04$.

[4] Of the 2400 trials (30 participants $\times$ 2 conditions $\times$ 40 trials) 10 trials were not available due to minimal errors in the protocol.

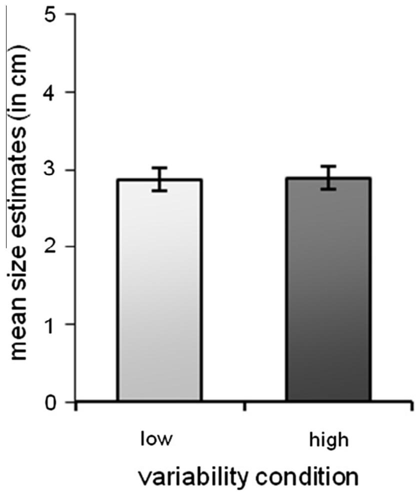

Fig. 3. Mean size estimates were computed separately for the low-variability condition and for the high-variability condition. Error bars represent the 95% confidence interval of the paired differences (Pfister & Janczyk, 2013).

4. Discussion

The current experiment examined the hypothesis put forward by Proffitt and Linkenauger (2013) that variability in performance outcome may scale the reported size of the target in an aiming task. While Cañal-Bruland et al. (2012) reported initial data in support for this assumption, the present study is the first to systematically investigate the independent influence of variability in performance outcome on size estimates of the aimed-at target.

Importantly, the manipulation of the vertical CE and VE in performance outcome was successfully implemented through the use of magnets. Accordingly, the vertical CEs were identical whereas the vertical VEs differed significantly between the two conditions. In keeping with Proffitt and Linkenauger (2013) and initial evidence supporting their hypothesis (Cañal-Bruland et al., 2012), we predicted that participants would report bigger sizes if the VE in performance outcome was smaller than if it was bigger. Our results do not confirm this prediction. Quite the reverse, the size estimates of the target were almost identical in both the low- and high-variability conditions, and hence independent of the VE in performance outcome. In other words, perceptual estimates remained stable in the face of variations in VE in performance outcome. This finding cannot be accounted for by a difference in horizontal variability, because our results clearly showed that the horizontal CE and VE remained unaffected by the high- and low-variability manipulations.

It may be argued that the experimental setting could have caused a decoupling of the self-generated action and performance outcome. While we cannot rule this argument out completely, we deem it unlikely to serve as an explanation of our findings. First, previous studies that actually have separated self-generated actions from performance outcomes have still reported skill-related differences in perception (Gray & Beilock, 2011; Gray, Beilock, & Carr, 2007). Second, during the experiment participants were explicitly told that the task would be difficult because of the invisible force field, but that the target could be hit if they slid the disk in the perfect direction and with perfect speed. In addition, they were advised that people tended to undershoot the target. Thus, our instruction emphasized the contribution of the participant's own actions independent of the force field.

We conclude that while our results contradict the assumptions put forward by Proffitt and Linkenauger (2013), they seem to be in accordance with recent theoretical and experimental criticisms on this matter (Durgin, Klein, Spiegel, Strawser, & Williams, 2012; Durgin et al., 2009; Firestone, 2013; Shaffer, McManama, Swank, & Durgin, 2013; Woods, Philbeck, & Danoff, 2009; but see Proffitt, 2013). We therefore feel that the experimental evidence reported here adds to the ongoing debate about embodied perception in general, and action-specific effects on size estimates in particular.

References

Cañal-Bruland, R., Pijpers, J. R. R., & Oudejans, R. R. D. (2012). Close, and a cigar! – Why size perception relates to performance. *Perception, 41*, 354–356. http://dx.doi.org/10.1068/p7255.

Cañal-Bruland, R., & van der Kamp, J. (2009). Action goals influence action-specific perception. *Psychonomic Bulletin & Review, 16*, 1100–1105. http://dx.doi.org/10.3758/PBR.16.6.1100.

Cañal-Bruland, R., Zhu, F. F., van der Kamp, J., & Masters, R. S. W. (2011). Target-directed visual attention is a prerequisite for action-specific perception. *Acta Psychologica, 136*, 285–289. http://dx.doi.org/10.1016/j.actpsy.2010.12.001.

Cooper, A. D., Sterling, C. P., Bacon, M. P., & Bridgeman, B. (2012). Does action affect perception or memory? *Vision Research, 62*, 235–240. http://dx.doi.org/10.1016/j.visres.2012.04.009.

Durgin, F. H., Baird, J. A., Greenburg, M., Russell, R., Shaughnessy, K., & Waymouth, S. (2009). Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin & Review, 16*(5), 964–969. http://dx.doi.org/10.3758/PBR.16.5.964.

Durgin, F. H., Klein, B., Spiegel, A., Strawser, C. J., & Williams, M. (2012). The social psychology of perception experiments: hills, backpacks, glucose, and the problem of generalizability. *Journal of Experimental Psychology. Human Perception and Performance, 38*, 1582–1595. http://dx.doi.org/10.1037/a0027805.

Firestone, C. (2013). How "paternalistic" is spatial perception? Why wearing a heavy backpack doesn't-and couldn't-make hills look steeper. *Perspectives on Psychological Science, 8*, 455–473. http://dx.doi.org/10.1177/1745691613489835.

Gray, R. (2013). Being selective at the plate: Processing dependence between perceptual variables relates to hitting goals and performance. *Journal of Experimental Psychology: Human Perception and Performance, 39*, 1124–1142. http://dx.doi.org/10.1037/a0030729.

Gray, R. (2014). Embodied perception in sport. *International Review of Sport and Exercise Psychology, 7*, 72–86. http://dx.doi.org/10.1080/1750984x.2013.871572.

Gray, R., & Beilock, S. L. (2011). Hitting is contagious: Experience and action induction. *Journal of Experimental Psychology: Applied, 71*, 49–59. http://dx.doi.org/10.1037/a0022846.

Gray, R., Beilock, S. L., & Carr, T. M. (2007). "As soon as the bat met the ball, I knew it was gone": Outcome prediction, hindsight bias, and the representation and control of action in novice and expert baseball players. *Psychological Bulletin & Review, 14*, 669–675. http://dx.doi.org/10.3758/BF03196819.

Pfister, R., & Janczyk, M. (2013). Confidence intervals for two sample means: Calculation, interpretation, and a few simple rules. *Advances in Cognitive Psychology, 9*, 74–80. http://dx.doi.org/10.2478/v10053-008-0133-x.

Proffitt, D. R. (2006). Embodied perception and the economy of action. *Perspectives on Psychological Science, 1*, 110–122. http://dx.doi.org/10.1111/j.1745-6916.2006.00008.x.

Proffitt, D. R. (2013). An embodied approach to perception: By what units are visual perceptions scaled? *Perspectives on Psychological Science, 8*, 474–483. http://dx.doi.org/10.1177/1745691613489837.

Proffitt, D., & Linkenauger, S. (2013). Perception viewed as a phenotypic expression. In W. Prinz, M. Beisert, & A. Herwig (Eds.), *Action science: Foundations of an emerging discipline* (pp. 171–198). Cambridge, Mass.: MIT Press.

Shaffer, D. M., McManama, E., Swank, C., & Durgin, F. H. (2013). Sugar and space? Not the case: Effects of low blood glucose on slant estimation are mediated by beliefs. *i-Perception, 4*(3), 147–155. http://dx.doi.org/10.1068/i0592.

Wesp, R., Cichello, P., Gracia, E. B., & Davis, K. (2004). Observing and engaging in purposeful actions with objects influences estimates of their size. *Perception & Psychophysics, 66*, 1261–1267. http://dx.doi.org/10.3758/BF03194996.

Witt, J. K. (2011). Action's effect on perception. *Current Directions in Psychological Science, 20*, 201–206. http://dx.doi.org/10.1177/0963721411408770.

Witt, J. K., & Dorsch, T. E. (2009). Kicking to bigger uprights: Field goal kicking performance influences perceived size. *Perception, 38*, 1328–1340. http://dx.doi.org/10.1068/p6325.

Witt, J. K., Linkenauger, S. A., Bakdash, J. Z., & Proffitt, D. R. (2008). Putting to a bigger hole: Golf performance relates to perceived size. *Psychonomic Bulletin & Review, 15*, 581–585. http://dx.doi.org/10.3758/PBR.15.3.581.

Witt, J. K., & Proffitt, D. R. (2005). See the ball, hit the ball: Apparent ball size is correlated with batting average. *Psychological Science, 16*, 937–938. http://dx.doi.org/10.1111/j.1467-9280.2005.01640.x.

Witt, J. K., & Proffitt, D. R. (2008). Action-specific influences on distance perception: A role for motor simulation. *Journal of Experimental Psychology: Human Perception and Performance, 34*, 1479–1492. http://dx.doi.org/10.1037/a001078.

Woods, A. J., Philbeck, J. W., & Danoff, J. V. (2009). The various perceptions of distance: An alternative view of how effort affects distance judgments. *Journal of Experimental Psychology: Human Perception & Performance, 35*, 1104–1117. http://dx.doi.org/10.1037/a0013622.