Psychon Bull Rev
DOI 10.3758/s13423-014-0744-9

BRIEF REPORT

Visual illusions can facilitate sport skill learning

Guillaume Chauvel · Gabriele Wulf · François Maquestiaux

Abstract Witt, Linkenauger, and Proffitt (*Psychological Science*, *23*, 397–399, 2012) demonstrated that golf putting performance was enhanced when the hole was surrounded by small circles, making it look larger, relative to when it was surrounded by large circles, making it look smaller. In the present study, we examined whether practicing putting with small or large surrounding circles would have not only immediate effects on performance, but also longer-lasting effects on motor learning. Two groups of nongolfers practiced putting golf balls to a 10.4-cm circle ("hole") from a distance of 2 m. Small or large circles were projected around the hole during the practice phase. Perception of hole size was affected by the size of the surrounding circles. Also, self-efficacy was higher in the group with the perceived larger hole. One day after practice, participants performed the putting task, but without visual illusions (i.e., a retention test). Putting accuracy in retention was greater for the group that had practiced with the perceived larger hole. These findings suggest that the apparently larger target led to the more effective learning outcome.

Keywords Golf putting · Visual perception · Ebbinghaus illusion · Learning · Self-efficacy

Over the past few years, findings from different lines of research have provided converging evidence that the performer's mindset influences motor skill learning. Specifically, manipulations that enhanced learners' expectancies for performance success or made a task seem less intimidating have been found to facilitate learning. Some of these findings have come from investigations into the effects of different types of feedback. For instance, providing learners with feedback after relatively successful trials rather than less successful trials (unbeknownst to the learner) has been shown to result in more effective learning (e.g., Badami, VaezMousavi, Wulf, & Namazizadeh, 2012; Chiviacowsky & Wulf, 2007; Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012). Also, providing individuals with social-comparative information, such as (bogus) average performance scores of others, suggesting that their own performance was superior to that of the average learner, has been found to lead to more effective learning than under control conditions (e.g., Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012; Lewthwaite & Wulf, 2010; Wulf, Chiviacowsky, & Lewthwaite, 2010, 2012). Setting performance criteria that can be reached relatively easily has also been found to facilitate learning (e.g., Trempe, Sabourin, & Proteau, 2012). Finally, (edited) video feedback that shows the learner's good performances, rather than the actual or average performance, has been demonstrated to be effective for learning (e.g., Clark & Ste-Marie, 2007). What these manipulations have in common is that they increase the performers' perceptions of competence (Badami, VaezMousavi, Wulf, & Namazizadeh, 2011; Saemi, Wulf, Ghotbi-Varzaneh, & Zarghami, 2011) or self-efficacy (Badami et al., 2012; Saemi et al., 2012; Wulf et al., 2012). The positive relation between self-efficacy and motor performance is generally well established (e.g., Feltz, Chow, & Hepler, 2008; for a meta-analysis of 45 studies, see Moritz, Feltz, Fahrbach, & Mack, 2000). Moreover, self-efficacy has been shown to be a mediator of motor learning (e.g., Stevens, Anderson, O'Dwyer, & Williams, 2012), perhaps because high levels of self-efficacy facilitate the adoption of implicit strategies known to promote the development of procedural knowledge (Chauvel et al., 2012; Masters, Poolton, & Maxwell, 2008).

G. Chauvel (✉)
Faculté de médecine, Université Jean Fourier, Bât Jean Roget, 38706 La Tronche Cedex, Grenoble, France
e-mail: guillaume.chauvel@imag.fr

G. Wulf
University of Nevada, Las Vegas, Las Vegas, NV, USA

F. Maquestiaux
Université de Franche-Comté, Besançon, France

Published online: 15 October 2014

Interestingly, motor performance can even be influenced by beliefs or suggestions that certain devices will aid performance (Lee, Linkenauger, Bakdash, Joy-Gaba, & Proffitt, 2011), by superstition (Damisch, Stoberock, & Mussweiler, 2010), or by visual illusions (Witt, Linkenauger, & Proffitt, 2012). For instance, Witt and colleagues (see also Wood, Vine, & Wilson, 2013) examined whether visual illusions affecting the perceived size of the golf hole would influence putting accuracy. They found that, when the golf hole appeared larger because it was surrounded by small circles (Ebbinghaus illusion), participants produced more successful putts than when the hole was surrounded by larger circles, and therefore appeared smaller. In that study and other studies (Damisch et al., 2010; Lee et al., 2011), the focus was on immediate performance, rather than learning (i.e., relatively permanent effects as a function of practice; Schmidt & Lee, 2011).

The main purpose of the present study was to investigate whether visual illusions can have more than a temporary effect on motor performance (Witt et al., 2012; Wood et al., 2013) and have the capacity to influence motor learning. To this end, we used a golf putting task similar to that of Witt and colleagues (Witt et al., 2012; Wood et al., 2013). Two groups practiced the task with the hole being surrounded by smaller or larger circles, in an attempt to induce visual illusions that would make the hole appear larger or smaller, respectively. Learning was then assessed through a retention test on the following day with the surrounding circles removed. Witt et al. speculated that perceived hole size might have influenced participants' self-confidence and in turn their putting performance. Yet, no measure of self-efficacy was included in their study. Therefore, another purpose of the present study was to assess learners' self-efficacy. If the perception of a larger hole makes the task appear less difficult, one would expect to see increased self-efficacy relative to a perceived smaller hole. This prediction is strengthened by previous empirical evidence demonstrating that decreasing task difficulty increases self-efficacy (Stevens et al., 2012). Here we measured participants' self-efficacy as a function of practice condition at various points in time during the experiment. This measurement also allowed us to examine whether self-efficacy would predict practice performance or learning (i.e., retention performance) in terms of perceived hole size.

Method

Participants

Thirty-six undergraduate students (20 females, 16 males), with an average age of 21.7 years (*SD* = 1.25) and little or no experience playing golf, participated in the experiment. The participants were naive as to the purpose of the study, and they gave their written informed consent before participation. The study was approved by the university's institutional review board.

Apparatus and task

Participants were asked to putt golf balls to a horizontal circular target resembling a standard golf hole (10.4 cm in diameter) on a level artificial-turf indoor green (400 × 55 cm). A projector that was suspended from the ceiling was used to project the "hole" and a ring of either 11 small circles (3.8 cm in diameter) or five large circles (28 cm in diameter) around the target, in an attempt to create an Ebbinghaus illusion (see Fig. 1). Participants putted from a distance of 2 m using standard white golf balls. Putting accuracy was measured as the distance between the center of the hole and the edge of the ball. If a ball contacted the rear border of the putting green, the maximum measurable deviation of 100 cm was recorded. (This was the case for 20.0 % of pretest trials and 2.8 % of the practice or retention trials.)

Procedure

Participants were randomly assigned to one of two groups: A group that practiced with small circles surrounding the target (perceived larger hole) or one that practiced with large circles surrounding the target (perceived smaller hole). Each participant first completed a pretest consisting of five trials without surrounding circles. Subsequently, the respective circles were projected around the target. Participants, standing in the position from which they putted, were asked to draw the target circle on a laptop computer using Microsoft Paint, trying to match the actual diameter of the target (Lee et al., 2011). To ensure that they drew circles, and not ovals, they were asked to make sure that the number of pixels in the x and y directions were identical. The diameters of the drawn circles were later measured to verify that the perceptions of target size indeed differed between the groups. Subsequently, participants filled out a self-efficacy questionnaire on which they rated their confidence, on a scale from 1 (*not confident at all*) to 10 (*extremely confident*), of being able to achieve average deviations of 20, 15, 10, and 5 cm or less on the last ten practice trials (Trials 41–50). They then performed five blocks of ten practice trials. They were instructed to try to make the ball stop as close to the target as possible. In addition to their intrinsic visual feedback, during Blocks 1, 3, and 5, participants were given feedback (deviations in centimeters) after each trial, primarily to provide a basis for future self-efficacy assessments. After the completion of the practice phase, participants were again asked to estimate the size of the target circle by drawing it on a laptop computer and to fill out another self-efficacy questionnaire in which they rated their confidence in their ability to produce certain average deviations (20, 15, 10, and 5 cm or less) on the following day. On Day 2 (the retention test), all participants

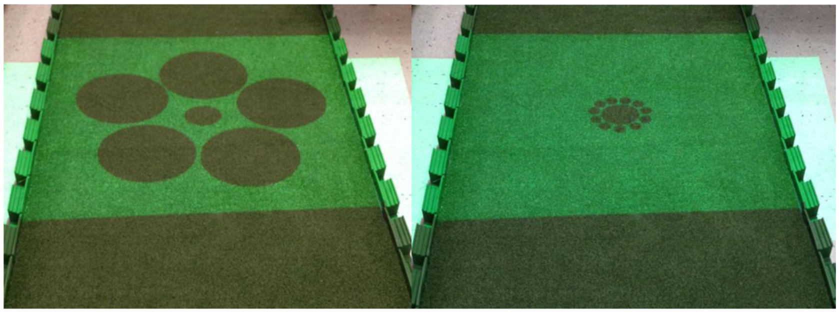

Fig. 1 Targets ("holes") and surrounding circles used to create the Ebbinghaus illusion

were first asked to draw the target circle and to fill out a self-efficacy questionnaire regarding their subsequent performance. They then performed the retention test per se, which consisted of one block of ten trials, but without the surrounding circles, to examine possible learning differences as a function of the practice groups (the group with the perceived smaller hole vs. the group with the perceived larger hole).

Data analysis

To assess putting performance, deviations from the target were averaged across five trials for the pretest and across ten trials for the practice phase and retention test. Univariate analyses of variance (ANOVAs) were used for the pretest and retention test, and a 2 (groups) × 5 (blocks of ten trials) ANOVA with repeated measures on the last factor to analyze the practice data. Both perceived hole size (in centimeters) and self-efficacy scores, averaged across the four questions on each questionnaire, were analyzed in a 2 (groups) × 2 (time: before practice, after practice) repeated measures ANOVA, for the practice phase, and a one-way ANOVA, for the retention test. Finally, we conducted linear regression analyses to determine whether self-efficacy predicted performance during practice or retention and whether the practice and retention performances were related.

Results

Perceived hole size

The sizes of the hole were perceived differently in the two groups. When the hole was surrounded by large circles, its perceived size was smaller than when it was surrounded by small circles (see Fig. 2, left and middle). This was the case before and after practice on Day 1, with the main effect of group being significant, $F(1, 32) = 4.19$, $p < .05$, $\eta_p^2 = .12$.[1] The main effect of time and the interaction of group and time were not significant, $F\text{s}(1, 32) < 1$. Before the retention test without the surrounding circles, perceptions of hole size (see Fig. 1, right) did not differ significantly between groups, $F(1, 34) < 1$.

Putting accuracy

The two groups' putting performance on the pretest did not differ significantly, $F(1, 34) = 1.65$, $p > .05$. During the practice phase, both groups reduced their deviations from the hole (see Fig. 3, left), as was evidenced by the significant main effect of block, $F(4, 136) = 6.26$, $p < .001$, $\eta_p^2 = .16$. Particularly toward the end of practice, the group with the perceived larger hole demonstrated greater accuracy than did the group with the perceived smaller hole, as was suggested by a significant interaction of group and block, $F(4, 136) = 2.75$, $p < .05$, $\eta_p^2 = .08$ (even though post-hoc tests did not reveal the source of the interaction). The main effect of group was not significant, $F(1, 34) = 1.47$, $p > .05$.

On the retention test without surrounding circles one day later (Day 2), deviations from the hole were smaller for the group with the perceived larger hole during practice ($M = 27.1$ cm) than for the group with the perceived smaller hole size ($M = 35.9$ cm) (see Fig. 3, right), $F(1, 34) = 10.27$, $p < .01$, $\eta_p^2 = .23$. The main effect of group was still significant when self-efficacy assessed right after the practice phase, $F(1, 33) =$

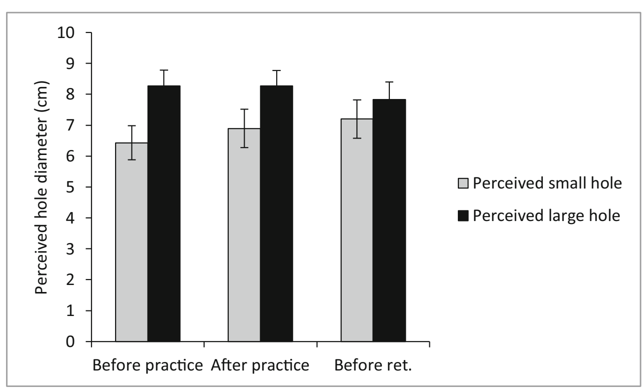

Fig. 2 Perceived hole size before practice (i.e., after the pretest), at the end of practice, and before the retention test, as a function of the type of visual illusion (hole perceived as small vs. hole perceived as large)

[1] Due to technical issues, the circle drawings of two participants in the group with the perceived smaller circle were lost.

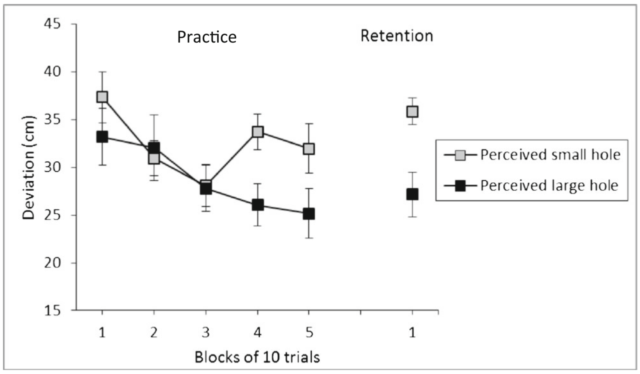

Fig. 3 Putting performance (i.e., deviations from the hole) of the two groups during practice (with visual illusion) and retention (without visual illusion)

8.23, $p < .01$, $\eta_p^2 = .20$, or just before the retention test, $F(1, 33) = 8.47$, $p < .01$, $\eta_p^2 = .20$, was included as a covariate. Thus, the apparently larger hole size during practice benefited the learning of this task.

Self-efficacy

Self-efficacy scores can be seen in Fig. 4. The group with the perceived larger hole reported higher self-efficacy than did the group with the perceived smaller hole, both before and after practice. The main effect of group was significant, $F(1, 34) = 4.43$, $p < .05$, $\eta_p^2 = .12$. Neither the main effect of time, $F(1, 34) < 1$, nor the interaction of group and time, $F(1, 34) = 1.60$, $p > .05$, was significant. Before the retention test on Day 2 (without the surrounding circles), the main effect of group failed to reach significance, $F(1, 34) = 3.14$, $p = .086$, $\eta_p^2 = .08$.

Regression analysis

Self-efficacy, assessed before practice and after the circles surrounding the hole were displayed, predicted performance during practice, $F(1, 34) = 8.58$, $p < .01$, $r = .45$, explaining 20 % of the variance. Self-efficacy was not a significant predictor of retention performance, $F(1, 34) = 1.21$, $p > .05$, though. Yet, practice performance did predict retention performance, $F(1, 34) = 51.67$, $p < .001$, $r = .64$, explaining 41 % of the variance.

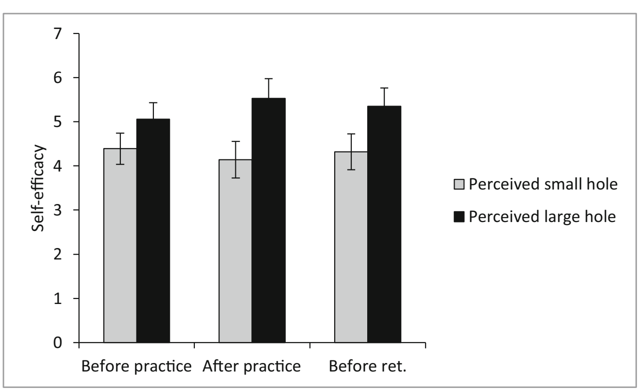

Fig. 4 Self-efficacy of the two groups before practice (i.e., after the pretest), after practice, and before the retention test, as a function of the perceived sizes of the hole across the groups (small vs. large)

Discussion

In the present study, we used a learning paradigm to examine whether previously found performance effects resulting from visual illusions (Witt et al., 2012; Wood et al., 2013) reflected only temporary influences that were dependent on the presence of the illusion (i.e., small or large circles surrounding the golf hole), or whether practicing under the respective conditions would have more permanent effects on task learning. The results showed that the size of the circles surrounding the 10.4-cm hole affected participants' perceptions of hole size (in contrast to the study by Witt et al., 2012, in which an Ebbinghaus illusion was observed only for a 5-cm hole, but not for a 10-cm hole). Also, the putting performance of the groups diverged during practice, and the group with the perceived larger hole outperformed the group with the perceived smaller hole toward the end of practice. Although the effect of perceived hole size across practice was relatively small, it had a relatively large impact on learning, as measured by the retention test the day after. Retention performance was clearly enhanced in the group with the larger relative to the smaller perceived hole size—even though the visual illusions were removed during that test.

In previous studies, self-efficacy or confidence as a function of visual illusion was not measured (Witt et al., 2012) or did not differ between groups with different perceptions of hole size (Wood et al., 2013). In the present study, self-efficacy during practice was found to be higher in the group with the larger perceived hole size. Furthermore, self-efficacy before the practice phase predicted practice performance, and putting accuracy during practice in turn was a significant predictor of task learning (i.e., retention performance). One limitation of the present study is related to the relatively small sample size ($N = 36$), which precluded determining whether self-efficacy played a causal role in the influence of perceived hole size on motor learning. Future research using larger sample sizes may help elucidate this issue—for instance, by examining whether those participants with greater self-efficacy following practice are also those who learn the best.

The picture that is emerging from this and other lines of research is that positive changes in mindset—be they through suggestions that one is performing well (e.g., Saemi et al., 2012; Trempe et al., 2012), that one's peers typically do well on a certain task (Wulf et al., 2012, Exp. 2), and even superstitious beliefs (e.g., Damisch et al., 2010) or visual illusions that make a task appear easier (Witt et al., 2012; Wood et al., 2013; present study)—have the capacity to improve performance and learning. The present findings add an important component to this picture by showing that the effect of visual illusions is not dependent on the presence of that illusion. Rather, practice with a "favorable" illusion appears to have beneficial longer-term effects on skill learning, since these effects were still seen the day after, when the illusion was removed. Future research may seek to determine whether such effects last for longer time intervals, such as weeks or even months.

From an applied perspective, the present findings suggest that the learning of motor skills that require hitting a target (e.g., dart throwing, shooting, or archery) might benefit from creating illusions that make the target appear larger. As the present findings demonstrate, the resulting performance improvements and increases in performers' confidence seem to have the capacity to transfer to situations in which the illusion is no longer present (e.g., competitions). Future studies will likely help to elucidate the generalizability of the findings to different tasks and circumstances, and to different populations (e.g., children, older adults, or sport experts).

References

Ávila, L. T. G., Chiviacowsky, S., Wulf, G., & Lewthwaite, R. (2012). Positive social-comparative feedback enhances motor learning in children. *Psychology of Sport and Exercise, 13,* 849–853.

Badami, R., VaezMousavi, M., Wulf, G., & Namazizadeh, M. (2011). Feedback after good versus poor trials affects intrinsic motivation. *Research Quarterly for Exercise and Sport, 82,* 360–364.

Badami, R., VaezMousavi, M., Wulf, G., & Namazizadeh, M. (2012). Feedback about more accurate versus less accurate trials: Differential effects on self-confidence and activation. *Research Quarterly for Exercise and Sport, 83,* 196–203.

Chauvel, G., Maquestiaux, F., Hartley, A. A., Joubert, S., Didierjean, A., & Masters, R. (2012). Age effects shrink when motor learning is predominantly supported by nondeclarative, automatic memory processes: Evidence from golf putting. *Quarterly Journal of Experimental Psychology, 65,* 25–38.

Chiviacowsky, S., & Wulf, G. (2007). Feedback after good trials enhances learning. *Research Quarterly for Exercise and Sport, 78,* 40–47.

Clark, S. E., & Ste-Marie, D. M. (2007). The impact of self-as-a-model interventions on children's self-regulation of learning and swimming performance. *Journal of Sports Sciences, 25,* 577–586.

Damisch, L., Stoberock, B., & Mussweiler, T. (2010). Keep your fingers crossed! How superstition improves performance. *Psychological Science, 21,* 1014–1020. doi:10.1177/0956797610372631

Feltz, D. L., Chow, D. M., & Hepler, T. J. (2008). Path analysis of self-efficacy and diving performance revisited. *Journal of Sport and Exercise Psychology, 30,* 401–411.

Lee, C., Linkenauger, S. A., Bakdash, J. Z., Joy-Gaba, J. A., & Proffitt, D. R. (2011). Putting like a pro: The role of positive contagion in golf performance and perception. *PLoS ONE, 6,* e26016. doi:10.1371/journal.pone.0026016

Lewthwaite, R., & Wulf, G. (2010). Social-comparative feedback affects motor skill learning. *Quarterly Journal of Experimental Psychology, 63,* 738–749.

Masters, R. S. W., Poolton, J. M., & Maxwell, J. P. (2008). Stable implicit motor processes despite aerobic locomotor fatigue. *Consciousness and Cognition, 17,* 335–338. doi:10.1016/j.concog.2007.03.009

Moritz, S. E., Feltz, D. L., Fahrbach, K., & Mack, D. (2000). The relation of self-efficacy measures to sport performance: A meta-analytic review. *Research Quarterly for Exercise and Sport, 71,* 280–294.

Saemi, E., Porter, J. M., Ghotbi-Varzaneh, A., Zarghami, M., & Maleki, F. (2012). Knowledge of results after relatively good trials enhances self-efficacy and motor learning. *Psychology of Sport and Exercise, 13,* 378–382.

Saemi, E., Wulf, G., Ghotbi-Varzaneh, A., & Zarghami, M. (2011). Feedback after good versus poor trials enhances motor learning in children. *Brazilian Journal of Physical Education and Sport, 25,* 671–679.

Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning* (5th ed.). Champaign, IL: Human Kinetics.

Stevens, D., Anderson, D. I., O'Dwyer, N. J., & Williams, A. M. (2012). Does self-efficacy mediate transfer effects in the learning of easy and difficult motor skills? *Consciousness and Cognition, 21,* 1122–1128. doi:10.1016/j.concog.2012.03.014

Trempe, M., Sabourin, M., & Proteau, L. (2012). Success modulates consolidation of a visuomotor adaptation task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 52–60.

Witt, J. K., Linkenauger, S. A., & Proffitt, D. R. (2012). Get me out of this slump! Visual illusions improve sports performance. *Psychological Science, 23,* 397–399. doi:10.1177/0956797611428810

Wood, G., Vine, S. J., & Wilson, M. R. (2013). The impact of visual illusions on perception, action planning, and motor performance. *Attention, Perception, & Psychophysics, 75,* 830–834. doi:10.3758/s13414-013-0489-y

Wulf, G., Chiviacowsky, S., & Lewthwaite, R. (2010). Normative feedback effects on learning a timing task. *Research Quarterly for Exercise and Sport, 81,* 425–431.

Wulf, G., Chiviacowsky, S., & Lewthwaite, R. (2012). Altering mindset can enhance motor learning in older adults. *Psychology and Aging, 27,* 14–21.