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ORIGINAL RESEARCH

The Effect of Large Visual Illusion and External Focus of Attention on Gaze Behavior and Learning of Dart Throw Skill

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Research has shown that large visual illusions and an external focus of attention can improve novice's motor learning. However, the combined effects of these approaches and the underlying mechanisms have yet to be studied. Therefore, the present study examined the effects of a large visual illusion and an external focus on the learning of a dart throwing task in novices and measured the perceptual mechanisms underpinning learning using quiet eye. Forty novice participants were randomly divided into four groups: large visual illusion, external focus of attention, combined large visual illusion and external focus of attention, and control group. The study consisted of a pretest, a practice phase, an immediate retention test, a 24-hr retention test, and a transfer test. Results revealed that all groups increased throwing accuracy and quiet eye duration from pretest to immediate retention. In the immediate retention, 24-hr retention, and transfer test, large visual illusion had greater accuracy and longer quiet eye duration than the control group. In addition, there were no significant differences between the visual illusion and external focus groups for throwing accuracy and quiet eye duration. The findings suggest that combining large visual illusion and external focus can independently improve motor learning but combining these manipulations does not have additive benefits.

Keywords: OPTIMAL theory, Ebbinghaus illusion, quiet eye

The OPTIMAL (Optimizing Performance through Intrinsic Motivation and Attention for Learning) theory of motor learning posits that enhanced expectancies, autonomy support, and an external focus of attention are key motivational and attentional factors for effective motor performance and learning (Wulf & Lewthwaite, 2016). More specifically, these motivational and attentional factors make independent and interactive contributions to effective motor performance and learning by priming and optimizing the motor system through efficient goal–action coupling (An et al., 2021; Gruber et al., 2016; Lappin et al., 2009; Wulf &

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Q3 Lewthwaite, 2016; Wulf et al., 2017). In motor learning research, expectations for success have been enhanced using various manipulations (for review, see Bacelar et al., 2022), including manipulations when increase perceptions of success by reducing perceived task difficulty using optical/visual illusions (e.g., Palmer et al., 2016). For example, previous studies have used the Ebbinghaus illusions to alter the perceived size of a central target through the manipulation of surrounding inducers. Large inducers result in central targets appearing perceptually smaller while small inducers make central targets appear larger (de Fockert & Wu, 2009; Roberts et al., 2005; see Figure 1).

Research on golf putting has found that visual illusions that make targets appear perceptually larger, increased putting accuracy compared perceptually smaller targets (Bahmani et al., 2017; Chauvel et al., 2015; Marchant et al., 2019; Witt et al., 2012). Moreover, visual illusions that increased perceived central target size have improved self-efficacy and perceived target size in golf putting, suggesting that implicit perceptual manipulations are effective in enhancing a learner's expectations for task success (Bahmani et al., 2017; Chauvel et al., Q4 2015; Marchant et al., 2018; Palmer et al., 2016). According to OPTIMAL theory, conditions which enhance expectancies positively influence performance through efficient goal–action coupling (Wulf & Lewthwaite, 2016) and a reduction in a detrimental self-related focused attention (McKay et al., 2015). That is, in addition to its motivational role, visual illusions could also indirectly promote or clarify an external focus of attention (Marchant et al., 2018, 2019; McKay et al., 2015; Pascua et al., 2015; Simpson et al., 2020; Stevens et al., 2012).

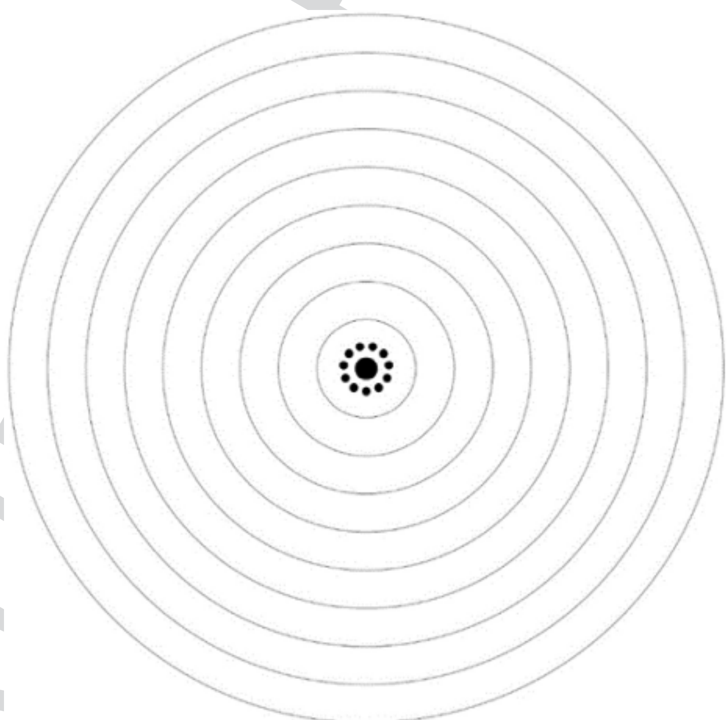
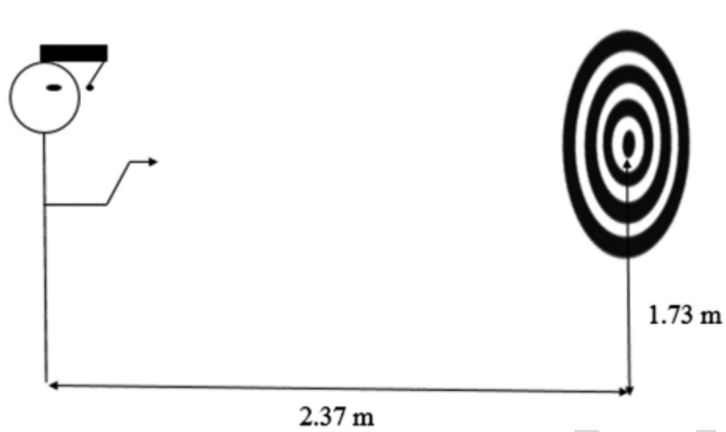


Figure 1 — Ebbinghaus illusion used to increase perceived target size.



Q5 **Figure 2** — Experimental setup.

Contrary to these findings, Cañal-Bruland et al. (2016) revealed that a small visual illusion improved marble shooting performance from pretest to posttest, whereas the large visual illusion group did not show any performance improvements. However no between-group differences where observed (Cañal-Bruland et al., 2016). Additionally, Bahmani et al. (2017) examined the effects of visual illusions on highly skilled rifle and pistol shooters. They found that large perceptual targets improved shooting accuracy and confidence compared to small perceptual targets immediately after practice, however no learning effects were
Q6 observed. Moreover, Maquestiaux et al. (2020) found that the Ebbinghaus visual illusion had no impact on novice golf-putting performance. These studies suggest that enhancing expectancies via implicit manipulations for success may not be effective for improving motor performance and learning highlighting the need for further research.

In addition to enhancing expectancies, verbal instruction and feedback which promotes an external focus of attention (i.e., a focus on the intended movement outcome or effect) has consistently demonstrated to augment motor performance and learning compared to an internal focus (i.e., on body movements) and no specific attentional focus (for reviews, see Chua et al., 2021; Wulf, 2013; Wulf & Lewthwaite, 2016). The OPTIMAL theory highlights that external focus improves movement efficiency (e.g., muscle activity; Porter et al., 2012) and movement effectiveness (e.g., throwing accuracy; Lohse et al., 2014) by promoting automatic, unconscious and reflexive motor control; and by reducing attentional demands allowing the learner to harness the self-organizing tendencies of the motor system (Kal et al., 2013; Lohse et al., 2010, 2014; Müller & Loosch, 1999; Wulf & Lewthwaite, 2016).

While the benefits of combining enhanced expectancies and an external focus have been demonstrated (e.g., Pascua et al., 2015; Wulf & Lewthwaite, 2016), only Marchant et al. (2019) have examined the potential combined effects of an external focus under illusory manipulations. They found positive independent effects of both an external focus of attention and a large visual illusion on golf putting performance, however combining OPTIMAL factors did not produce additive motor learning benefits contrasting OPTIMAL theory predictions and some previous research (Pascua et al., 2015; Wulf & Lewthwaite, 2016). Moreover, Marchant et al. (2019) failed to capture how the visual context (i.e., illusion) interacts with instruction in terms of visual processing despite visual context impacting perceptual and motor planning processes (Wood et al., 2013). Specifically, Wood and colleagues explored the mechanisms underpinning the Ebbinghaus illusion during golf-putting performance using the planning control model (Glover, 2002; Glover & Dixon, 2001). The authors found that the Ebbinghaus illusion biased perceptual judgments of the target and subsequent performance was influenced through altered motor planning process as evidenced through different quiet eye duration (QED)—an objective measure of motor planning in aiming tasks (Glover, 2004; Mann et al., 2007, 2011; Vickers, 2016; Wood et al., 2013).

The quiet eye has been defined as the final fixation prior to movement execution and reflects a period of crucial cognitive processing where relevant cues (e.g., target related information) are organized to optimize motor responses (i.e., motor planning processes; Vickers, 1996; Williams et al., 2002; Wilson & Pearcy, 2009). Specifically, the quiet eye occurs when the final fixation on a target exceeds 100 ms and remains within 3° of the visuomotor workspace (i.e., the intended visual task goal; Vickers, 2016). Therefore, the quiet eye can be conceptualized as an objective measure of motor planning processes in far aiming tasks—like dart throwing—(Mann et al., 2007, 2011) where longer QED have been associated with more effective preprogramming of critical parameters for superior task performance (Nibbeling et al., 2012; Querfurth et al., 2016; Rienhoff et al., 2012, 2013; Sammy et al., 2017; Vickers et al., 2000).

However, despite the benefits of a longer quiet eye and an external focus, research is limited in understanding whether performance advantages are mediated Q7 by covert (mental) or overt (visual) attention. For example, Land et al. (2013) reported that external focus benefits where not mediated by the online use of vision in a golf putting task, but instead, the clarity and relevance of external focused instructions may have greatly contributed to effective goal–action coupling (e.g., Petranek et al., 2019; Russell et al., 2014; Wulf & Lewthwaite, 2016). However, an external focus of attention has been shown to prolong QED (Ziv & Lidor, 2015), where an external focus may mediate the benefits of a longer QED (Causer et al., 2011; Gonzalez et al., 2017; Moore et al., 2012; Vine et al., 2011; Williams et al., 2002; Wilson & Pearcy, 2009; Wulf & Lewthwaite, 2016).

Contrastingly, visual illusion, which enhances expectancies for success, led to longer QED and more accurate golf putting performance potentially through clarifying an external focus on task goals (Moore et al., 2012; Wood et al., 2013). Yet, Razeghi et al. (2020) found that children with autism spectrum disorders produced more accurate golf putting under large visual illusion as compared to a control group but there were no significant differences in QED. Finally, Marchant et al. (2019) found that an external focus and large visual illusion improved motor performance independently but did not result in additive effects. These results suggest that any benefit of an external focus may still be informed by perceptual information however the authors did not record perceptual measures (i.e., QED). Nevertheless, previous research has demonstrated that the pairing of two OPTIMAL factors produced greater learning benefits suggesting that an external focus and enhanced expectancies assist learning through at least (partially) different pathways (Pascua et al., 2015; Wulf et al., 2018). Therefore, examining the potential independent and additive effects of an external focus and enhanced expectancies, while recoding perceptual measures to understand the underlying mechanisms of each OPTIMAL factor, is an important avenue for future research.

Although the effect of attentional instructions and visual illusions has been studied on gaze behavior separately, there is no research to-date examining the combined effects of these variables. Therefore, the present study aimed to explore the combined effects of a large visual illusion and external focus of attention on the learning of a dart throwing task and QED in novices. Based on previous studies, it was hypothesized that an external focus of attention and a large visual illusion would independently improve motor learning and produce longer QED as compared to the absence (Bahmani et al., 2017; Chauvel et al., 2015; Marchant et al., 2019; Wood et al., 2013; Wulf, 2013; Wulf & Lewthwaite, 2016). Moreover, we examined the potential positive additive effects of each factor (external focus and enhanced expectancies in the form of a large visual illusion) on motor performance and learning. In line with OPTIMAL theory predictions and previous research it was hypothesized that combining an external focus and large visual illusion would "double" the learning advantage and result in a longer QED as compared to each condition independently (Asadi et al., 2021; Marchant et al., 2019; Razeghi et al., 2020; Wulf & Lewthwaite, 2016).

Q8

Method

Participants

Q9

Using G-power software (version 3.1; Faul et al., 2007), a sample size of 36 participants was identified based on large effect size ($f = 0.25$), an alpha level of .05, and a power value of 0.80 (derived from Marchant et al., 2018). In total, 40 novice participants (32 females, eight males) aged 18–40 years were recruited for the study. Participants were randomly assigned to four groups: (a) large visual illusion (LVI; age: $M = 26.00 \pm 7.31$), (b) external focus of attention (EFA; age: $M = 24.60 \pm 4.00$), (c) combined large visual illusion and external focus of attention (LVI-EFA; age: $M = 26.30 \pm 6.48$), and (d) control (C; age: $M = 26.10 \pm 8.06$). Prior to participation, all participants provided informed consent and declared that they were free from any neurological, psychological, motor, or vision impairments. All participants were right-handed, which was determined by the hand they threw the dart with. All procedures were approved by the institutional review board of Shahid Beheshti University.

Task and Apparatus

A standard size dart board (diameter = 453 ± 3 mm) and dart (weight = 22 g) were used. The bull's eye was at a height of 1.73 m, and the throwing distance was 2.37 m. The bull's eye was surrounded by nine concentric circles. If the dart hit the bull's eye, 10 points were awarded by the experimenter in situ. Nine points were given for hitting the next circle, and so forth. If a dart hit a line separating two zones, the higher score was awarded. Throws that missed the target were awarded 0 points (Wulf et al., 2018). All throws were recorded, and the recordings were later used to determine the exact score if there was uncertainty during the testing session (see Figure 3).

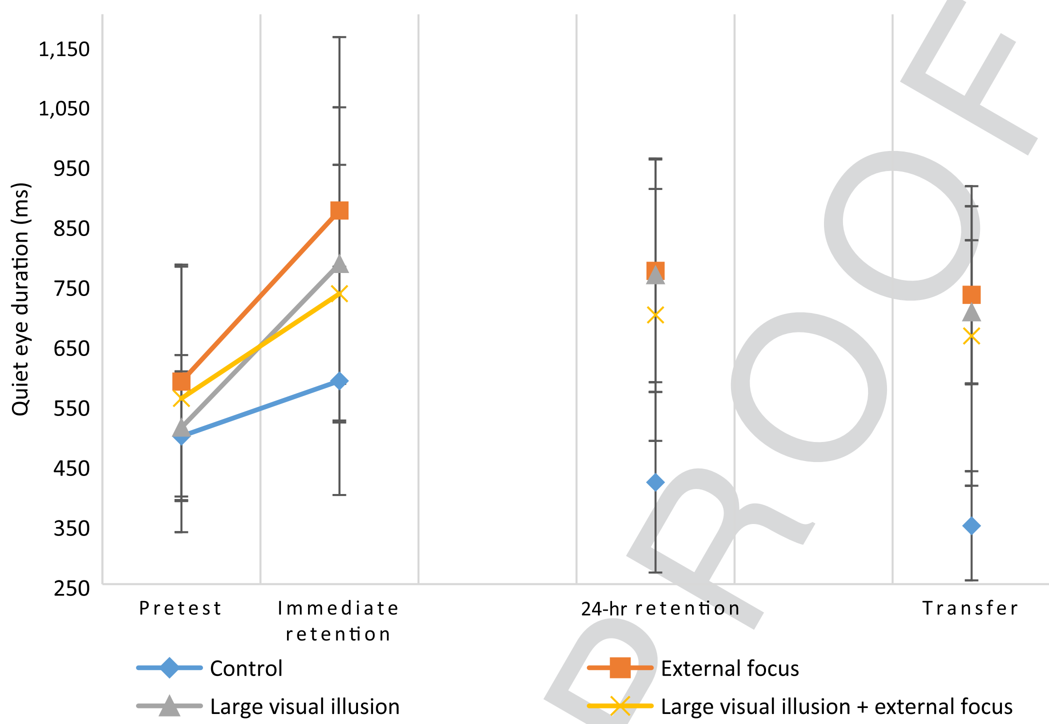


Figure 3 — Mean quiet eye duration (ms) during dart throwing performance.

Eye Movement Apparatus

A 120- Hz eye-tracking system (Pupil Labs) was used to measure gaze behaviors during dart throwing. Gaze behavior was recorded by two eye cameras (200 Hz) and a single world camera (60 Hz) at 720 × 1,280 resolution. A 5-point calibration was completed by asking participants to direct their gaze to the target surface (12, 3, 6, 9 O'clock and center positions) whilst in their throwing position before each block (Asadi et al., 2021). The calibration procedure was repeated as required. Gaze data from the eye tracker were recorded by Pupil capture software and analyzed by Pupil Player software (Pupil Labs). This allowed for the gaze behavior to be analyzed on a frame by frame basis to ensure that the critical movement components were analyzed. A side mobile camera (Samsung, 60 Hz at 1,920 × 1,080 resolution) was positioned 5 m on the right sagittal plane of the participants to record hand movements during each throw. The eye tracking and side cameras were synchronized with a laser light prior to the performance of each trial. The videos were later uploaded into Kinovea 0.8.15 video analysis software (https://www.kinovea.org/). This method allowed for the accurate synchronization of gaze and motor data to calculate the QED (Asadi et al., Q10 2021; Rienhoff et al., 2015; Vickers, 2007). QED for the throw, like other dart Q11 throwing research (Querfurth et al., 2016; Simpson et al., 2022), was calculated as the duration of final fixation on the circular targets before the extension of the throwing arm for dart release. This fixation point was within a three visual angle threshold for a minimum duration of 100 ms. QED was calculated as the duration of time between the onset of quiet eye (before extension of throwing arm) and the offset of quiet eye (when the fixation deviated off the target).

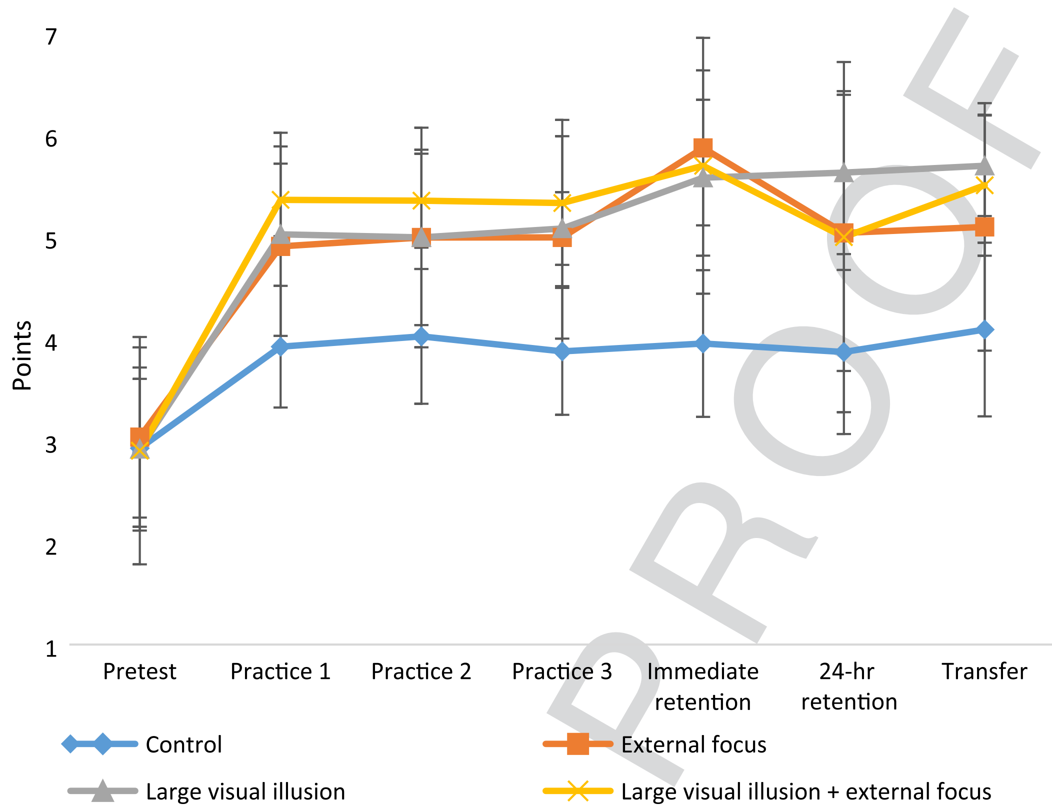


Figure 4 — Mean throwing accuracy scores over the duration of the study.

Procedures

Following informed consent, participants were instructed on the ideal way of performing the dart throw and were then randomly assigned to four groups: large visual illusion, external focus of attention, combined large visual illusion and external focus of attention, and control group (i.e., no visual illusion or external focus of attention). No attentional focus instructions were provided during this initial instruction. Following this, participants completed six familiarization trials without scoring to ensure they understood what was being asked. Participants were then fitted with eye-tracker glasses, and the device settings were adjusted, such as adjusting the angles of eye cameras, sample rate, and calibration. Next, participants performed a pretest which consisted of 12 trials without any instruction or feedback followed by the practice phase which began 24 hr later. The practice phase was spaced over 3 days, were on each day participants completed 10 blocks of 10 practice trials with 1-min rest periods between blocks. Darts were removed from the board every three trials. In the groups that included an external focus, participants were asked to "focus on the target and the path of the dart to the target." These instructions were given prior to each 10-trial block during the practice phase. In the illusion groups participants performed under the Ebbinghaus illusion (with the bull's eye surrounded by 11 small inducers (circles) so the target can be perceived as larger than its actual size). In the control group, participants received no attentional focus instructions and no visual illusion. After the last practice trial, an immediate retention test was administered, which was performed in the same manner as the pretest. One day later, 24-hr retention and transfer tests were performed, each consisting of 12 trials with no visual illusion and attentional instructions. Gaze behavior was recorded on the pretest, immediate retention, 24-hr retention, and transfer tests using the eye tracker.

Statistical Analysis

To analyze throwing accuracy a 2 (external focus/no external focus) × 2 (illusion/no illusion) × 7 (time) and a 2 (external focus/no external focus) × 2 (illusion/no illusion) × 4 (time; pre, immediate retention, 24-hr retention, transfer tests) mixed factor analysis of variance (ANOVA) with repeated measures on the final factor were used to examine throwing accuracy and QED respectively. Bonferroni post hoc analysis was applied if significance was observed. Alpha level was set at .05 for all analyses. Normality and homogeneity of variances were examined by the Shapiro–Wilk and Levin tests, respectively.

Results

Throwing Accuracy

The 2 (external focus/no external focus) × 2 (illusion/no illusion) × 7 (time) revealed a significant effect of time, $F(4.256, 153.201) = 53.586$, $p < .001$, $\eta_p^2 = .598$. Pairwise comparisons revealed that accuracy improved in all time points after pretest ($ps \leq .001$). Additionally, performance was better in the immediate retention test compared to practice Day 1 ($p = .024$) and 3 ($p = .023$) respectively.

Moreover, there was a significant Illusion × Time interaction, $F(4.256, 153.201) = 2.662$, $p = .032$, $\eta_p^2 = .069$, where accuracy was better in the visual illusion conditions during practice Day 1 ($p = .005$), practice Day 2 ($p = .017$), practice Day 3 ($p = .003$), immediate retention test ($p = .021$), 24-hr delayed retention test ($p = .043$), and transfer test ($p = .001$).

There was a significant effect for attentional focus where throwing accuracy was better under external focus as compared to no external focus conditions, $F(1, 36) = 9.067$, $p = .005$, $\eta_p^2 = .201$. Furthermore, there was a significant attentional focus × illusion interaction indicating that throwing accuracy was better when under external focus and no illusion conditions, $F(1, 36) = 10.686$, $p = .002$, $\eta_p^2 = .229$.

Quiet Eye Duration

The 2 (external focus/no external focus) × 2 (illusion/no illusion) × 4 (time; pre, immediate retention, 24-hr retention, transfer tests) revealed a significant Focus × Illusion × Time interaction effect, $F(3, 108) = 3.080$, $p = .031$, $\eta_p^2 = .079$. Pairwise comparisons indicated that QED was longer in the 24-hr retention test, $F\,(1, 36) = 21.317$, $p < .001$, $\eta_p^2 = .372$, and transfer test, $F(1,36) = 23.727$, $p < .001$, $\eta_p^2 = .397$) when both an external focus and large visual illusion were present as compared to an external focus with no illusion present.

Discussion

The present study aimed to explore the combined effects of a large visual illusion and external focus of attention on the learning of a dart throwing task and QED in novices. It was hypothesized that a large visual illusion and external focus of attention would improve dart throwing performance and prolong the QED as compared to a control group. Additionally, it was predicted that the combination of a large visual illusion and an external focus of attention would produce more accurate dart throws and longer QED compared to each condition independently (Wulf & Lewthwaite, 2016). The findings provide mixed support for our hypothesis.

First, in line with previous research, throwing accuracy was greater when participants were exposed to a large visual illusion (i.e., when the target was surrounded by smaller inducers) compared to no visual illusion (Bahmani et al., 2017; Chauvel et al., 2015; Witt et al., 2012; Ziv et al., 2019). Moreover, these findings support OPTIMAL theory predictions as enhancing expectancies for success via visual illusions facilitated motor performance and learning through more efficient goal–action coupling (Palmer et al., 2016; Wulf & Lewthwaite, 2016). Wulf and Lewthwaite (2016) explain that enhanced expectancies play a dual role in effective goal–action coupling and subsequent motor learning where learners with higher performance expectancies are better able to maintain a focus on task goals and have a reduced self-focus through the dopaminergic response associated with reward or expected success (i.e., expecting to hit or hitting the bull's eye; Schultz, 2010, 2013). Additionally, the longer QED observed in the large visual illusion group suggests that the implicit manipulation positively influenced visuomotor control which allowed for a greater focus on the task-goal supporting a previous study by Wood et al. (2013). Therefore, present study adds further support that conditions that enhance expectancies for success, through visual illusions, can facilitate efficient Q12 goal–action coupling for effective motor performance and learning.

However, the present findings were inconsistent with some studies (Bahmani et al., 2018; Cañal-Bruland et al., 2016; Maquestiaux et al., 2021). For example, Cañal-Bruland et al. (2016) revealed that the small visual illusion group improved performance from pretest to posttest, whereas large visual illusion group did not show any improvements on marble shooting. Potentially, the errors for learners in the large illusion condition were smaller than in the small illusion and control conditions in the pretest. Thus, there may have been little opportunity for improvement in the large illusion condition suggesting that implicit manipulations of success should provide sufficient challenge for learning to occur (Guadagnoli & Lee, 2004; Wulf & Lewthwaite, 2016). Additionally, Bahmani et al. (2018) found that highly skilled rifle and pistol shooters in large perceptual targets group had more accurate performance and more confidence than small perceptual targets group immediately after practice. However, in the retention test with no visual illusions, there were no differences between the two groups further suggesting that visual illusions require adequate challenge for learning to occur and enhancing expectancies alone (i.e., those that enhance perceptions of success) is not sufficient for motor learning (Hodges & Lohse, 2022).

In addition to the benefits of the implicit success manipulation (i.e., visual illusion) we found that an external focus of attention (onto the bull's eye and flight of the dart), lead to significantly greater throwing accuracy than as compared to no external focus conditions in line with previous finding (e.g., Chua et al., 2021). According to the OPTIMAL theory, an external focus of attention on the intended movement outcome or effect is predicted to improve movement efficiency movement efficiency (e.g., muscle activity; Porter et al., 2012) and movement effectiveness (e.g., throwing accuracy; Lohse et al., 2014) by promoting automatic, unconscious and reflexive motor control; and by reducing attentional demands allowing the learner to harness the self-organizing tendencies of the motor system (Kal et al., 2013; Lohse et al., 2010, 2014; Müller & Loosch, 1999; Wulf & Lewthwaite, 2016). The present findings add further evidence that an external focus is beneficial for novice motor learning.

However, the external focus benefit was not retained in the 24-hr retention and transfer tests. One potential explanation for this finding is that without explicit attentional focus instruction 24 hr after practice, novice participants may have adopted an internal focus of attention or no specific focus which does not facilitate motor learning (Porter et al., 2010; Wulf & Lewthwaite, 2016). However, no manipulation check was performed to confirm adherence to an external focus although longer QED in the immediate retention, 24-hr retention and transfer tests suggests that participants where effective in maintaining an overt external focus of attention of task-relevant cues (Asadi et al., 2021; Causer et al., 2011; Gonzalez et al., 2017; Moore et al., 2012; Vine et al., 2011; Williams et al., 2002; Wilson & Pearcy, 2009; Wulf & Lewthwaite, 2016; Ziv & Lidor, 2015). While the participants' covert attention cannot be assumed, the findings do not support OPTIMAL theory predictions that improved motor performance resulting from an external focus leads to greater motor learning. Future research should aim to measure both covert and overt attention orientations to better understand the mechanisms underpinning an external focus of attention (Querfurth et al., 2016).

The final hypothesis of the study predicted that combining a large visual illusion—which enhanced expectancies for success—and an external focus—would have additive motor learning benefits (Wulf & Lewthwaite, 2016). However, combining a large visual illusion and external focus did not yield greater learning advantages than each factor alone, contrasting previous research suggesting that each OPTIMAL factor assists learning through (partially) independent mechanisms (Pascua et al., 2015; Wulf et al., 2015, 2018). Nevertheless, the findings support Marchant et al. (2019) who also failed to find additive learning effects when a large visual illusion and external focus were combined. The present findings suggest that an external focus and enhanced expectancies (i.e., large visual illusion) share common mechanisms with neither adding additional value to the other's effect. Indeed, OPTIMAL theory posits that attentional (i.e., external focus) and motivational (i.e., visual illusion to enhance expectancies) factors are mediated through a common goal–action coupling mechanism (Wulf & Lewthwaite, 2016). For example, enhanced expectancies can protect against a task-irrelevant focus (i.e., self-referential processing) and strengthen a focus on the task goal (i.e., an external focus) by increasing a learner's assessment of their action capabilities (Linkenauger et al., 2009; Witt et al., 2014; Wulf & Lewthwaite, 2016). Additionally, an external focus further protects against self-referential processing by facilitating the efficient switching between the default mode network to task-relevant networks required for effective motor performance (McKay et al., 2015; Wulf & Lewthwaite, 2016). Indeed, QED was significantly longer in the 24-hr retention and transfer tests when the large visual illusion and external focus were present suggesting that combining implicit success manipulations and explicit external focus instructions was effective for increasing a focus on task-goal (i.e., hitting the bull's eye; Asadi et al., 2021; Causer et al., 2011; Gonzalez et al., 2017; Moore et al., 2012; Vine et al., 2011; Williams et al., 2002; Wilson & Pearcy, 2009; Wulf & Lewthwaite, 2016; Ziv & Lidor, 2015). Yet, the lack of associated performance improvements suggests that such conditions did not further facilitate effective goal–action coupling beyond an implicit success manipulation or external focus alone contradicting the OPTIMAL theory (Wulf & Lewthwaite, 2016). Taken together, the findings suggest that each manipulation is equally effective at coupling goals with intended actions and that motivational (i.e., enhanced expectancies) and attentional (i.e., external focus) interventions may not necessarily be separate mechanisms (Simpson et al., 2020; Wulf & Lewthwaite, 2016). While the findings provide support for the prediction that motor learning is mediated through common mechanisms (Marchant et al., 2019; Wulf & Lewthwaite, 2016), the results contrast previous research that an external focus and enhanced expectancies have additive effects on learning (Pascua et al., 2015; Wulf et al., 2015). Future research should continue to explore the perceptual and motor learning effects enhanced Q13 expectancies in conjunction with an EF (e.g., Wulf et al., 2018) to further investigate the potentially contradicting findings with OPTIMAL theory research and further understand the mechanisms underpinning motor learning.

The present study is not without its limitations. For example, no motivational measures were recorded (e.g., self-efficacy) therefore it is unclear whether the learning advantages associated with the large visual illusion were driven primarily by perceptual or motivational mechanisms. Future research should consider combining perceptual and motivational measurements to better test predictions of the OPTIMAL theory (Wulf & Lewthwaite, 2016). Additionally, future studies should increase the sample size; it is possible that the small sample size limited the statistical power whereby a larger sample size may have highlighted clear differences for the combination group. Finally, the authors acknowledge that measuring accuracy via radial error may provide a more precise assessment of precision as compared to a ring-scoring system (Hancock et al., 1995).

From a practical perspective, the present findings suggest that motor skill learning involving a target (e.g., dart throwing) might take advantage of visual illusions that enhance expectations for success (i.e., make targets appear larger). Additionally, practitioners should emphasize an external focus on the intended movement (e.g., target) to improve motor performance and learning. Overall, it appears that applying both external focus instructions and manipulating perceptions of success can improve perceptual and motor learning. Coaches, trainers, and teachers are recommended to use these strategies to improve motor skills in novices. Future research should continue determine the generalizability of these findings to different tasks (e.g., complex motor skills) and populations (e.g., children, experienced athletes).

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Queries

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