EFFECTS OF ATTENTIONAL FOCUS INSTRUCTIONS ON THE LEARNING OF A TARGET TASK: A MODERATION ROLE OF VISUAL FEEDBACK

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Abstract:

The present study examined whether visual feedback can have a moderating effect on the relation between attentional focus instructions and the learning of a target movement skill. Participants (N: 100, mean age: 21.0 years, SD: 2.1) were randomly assigned into visual feedback versus non-visual feedback groups. Each group was split into five subgroups: control, internal focus on the arm, and three external focus groups including focus on the dart, on the flight of the dart, and on the bull's-eye. Participants in each subgroup were asked to throw the darts at the dartboard using their specified focus instructions with either full-visual or non-visual information on results. The accuracy scores of throws were analyzed in 2 (visual groups) x 5 (focus subgroups) x 6 (trial blocks) analysis of variance with repeated measures on the last factor in acquisition, and 2 (visual groups) x 5 (focus subgroups) analysis of variance in retention and transfer. While the attentional focus instructions were not confirmed as a significant factor in practice, visual feedback was more beneficial than non-visual feedback in the acquisition of a target task. However, the benefits of practicing with visual feedback were not observed in the retention and transfer tests when vision was available. Furthermore, external focus on the flight of the dart was more beneficial than the other attentional focus instructions in transfer test, showing that the optimized distance of external focus of attention for the learning may change when a target task is executed on a stable or variable (moving) target.

Key words: *attention, vision, acquisition, aiming skill, retention, transfer*

Introduction

Ample investigations have illustrated that attentional focus instructions adopted by a performer are one of the most effective strategies in optimizing human actions including motor skills performance. The benefits of focusing attention on the indented outcome of the movement called *an external focus* rather than focusing attention on the execution of bodily movement called *an internal focus* have been demonstrated for acquisition of motor skills (e.g. McNevin & Wulf, 2002; Wulf, Höß, & Prinz, 1998; Wulf, Mercer, McNevin, & Guadagnoli, 2004; for review see Wulf, 2007, 2013), and observed in motor performance and learning in retention or transfer tests (e.g. McNevin, Shea, & Wulf, 2003, Wulf, et al., 1998; Wulf, Shea, & Park, 2001; for a review see Wulf, 2007). The positive effects of adopting an external focus of attention were also found for performance and learning of various types of sport-specific skills involved in some invasion and net/wall games such as a basketball free shooting task (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002), volleyball serve and soccer kick (Wulf, McConnel, Gartner, & Schwarz, 2002), throwing tennis balls at a target (Pascua, Wulf, & Lewthwaite, 2014), golf (Wulf, Lauterbach, & Tool, 1999; Wulf, McNevin, Fuchs, Ritter, & Toole, 2000), and a dart throwing task (Marchant, Clough, & Crawshaw, 2007).

To explain the benefits of an external focus of attention during the learning of movement skills, *constrained action hypothesis* was suggested (McNevin, et al., 2003; Wulf, 2013; Wulf, McNevin, & Shea, 2001). According to this hypothesis disruption in automatic control processes may occur when individuals focus their attention internally, while focusing attention externally may organize the automatic control processes more efficiently and effectively (Wulf, 2013). This hypothesis has emerged from "*the common-coding hypothesis"* (Prinz, 1990, 1997). As stated by this hypothesis, a commensurate coding procedure for action planning in relation to perception occurs when afferent and efferent codes are generated and maintained at a distal level of representation of action.

Recently, the optimized level of distance in external focus instructions at two levels "close or far distance" has also been the subject of debate in some research studies. Particularly, some investigations have shown that increasing the distance of an external focus of attention enhances motor learning (McKay & Wulf, 2012; McNevin, et al., 2003). For instance, McKay and Wulf (2012) have illustrated that dart throwing accuracy was enhanced when participants adopted a distal external focus by directing attention to the dartboard rather than a proximal focus by directing attention to the flight of the dart. In the other study on a dart throwing task, Lohse and colleagues (Lohse, Jones, Healy, & Sherwood, 2013)) compared the effects of internal focus on the motion of arm (IF-MA), versus external focus on the release of the dart (EF-RD), the flight of the dart (EF-FD), and the bull's-eye (EF-BE). The results demonstrated that participants in the external focus conditions on EF-FD and EF-BE performed with less errors than IF-MA. However, EF-FD was the most effective instruction relative to IF-MA.

Besides the attentional focus instructions, the role of concurrent visual feedback for acquiring motor skills has especially been considered for target tasks. The visual feedback can provide information on body movements, task environment and/or knowledge of results of an action (Schmidt & Lee, 2011). In fact, the advantages of external rather than internal focus of attention for skill learning/performance have mostly been illustrated in which participants looked at the target. For instance, subjects could receive visual feedback while and after performing trials of movement action in tossing a tennis ball (Saemi, Porter, Wulf, Ghotbi-Varzaneh, & Bakhtiari, 2013), basketball free throw (Zachry, Wulf, Mercer, & Bezodis, 2005), dart throwing task (Marchant, et al., 2007), discus throw (Zarghami, Saemi, & Fathi, 2012), and shot put (Makaruk, Porter, & Makaruk, 2013). The disadvantage of the internal focus on execution of bodily movements observed in these studies could be explained by a disruption in receiving visual feedback information during execution of an action.

The study by Perkins-Ceccato, Passmore, and Lee (2003) showed that there is no difference between internal versus external attentional focus groups when novice participants did not receive any visual information about the results of their action in acquisition of a golf swing task. In that study, opaque occlusion goggles prevented direct vision of performers' results after each instructional trial for reducing the effects of visual information about the results of the subsequent shots. In another piece of research on golf putting, Land and his colleagues (Land, Tenenbaum, Ward, & Marquardt, 2013) tested the role of visual information on the effectiveness of an external focus of attention. Conversely, they reported that the beneficial effects of focusing on the direction and speed of the ball (external focus) rather than focusing on a secondary tone-counting task (irrelevant focus) and no focus instructions did not rely on visual information during performance, or on access to knowledge of results.

According to Mass et al. (2008), there would be no optimizing schema unless four different sources of information—the relations among the initial conditions, the generated motor commands, the sensory consequences of the motor commands, and the outcome of the movement—are available following the movement. Based on this view, motor learning is associated with forming a connection among the various sources of information. For example, if a learner does not know whether the produced action was correct, then the schemas cannot be updated (Mass, et al., 2008). Therefore, the aim of the current study was to examine the effect of external versus internal focus instructions on acquiring a target task practiced under the condition of visual and no visual information about the result of an action. We wanted to address the question of whether the benefits of external focus instructions depend on visual access to knowledge of action results. We assumed that the beneficial effects of an external focus of attention are independent of visual feedback for a target task. In addition, as regards the external focus instructions specifically, we also tested the level of distance of external focus progressively to find out which set of instructions is optimal as a factor of motor learning for a target skill. Our assumption was that focusing attention externally on longer distances would be more beneficial than focusing attention on distances closer to the body movements.

Methods

Ethics

As the part of the research project, the protocols were submitted and approved by the review board of the university. Informed consent was used to gain written permission from the subjects participating in the study.

Participants

Female college students (N=100, mean age: 21.0, SD: 2.1 years, range 18–25 years), with no previous experience in a dart throwing task and without physical or mental disabilities, participated in this study. The other inclusion criterion was right-handed functional dominance identified by the Edinburgh Handedness Inventory (Oldfield, 1971).

Apparatus and the target task

The participants were asked to throw darts at a dartboard. The dartboard was 40 cm in diameter, with nine concentric rings, each 2 cm in width, and a 2 cm diameter bull's-eye in the center. The dartboard was installed so that the bull's-eye was 1.70 m above the floor and participants stood 2.50 m from the dartboard. The task was to throw regular-sized darts at the bull's-eye on the dartboard. A dart that struck the bull's-eye received a score of 10 points, with a dart that struck the outermost ring receiving a score of 1, and so forth. Shots that missed the board entirely were given 0 points.

Procedures

Before the beginning of the experiment, all participants were asked to throw two darts to become familiar with the task. There was no instruction in this phase. Then, according to the average of warm-up scores, participants were randomly divided into two groups, one with visual feedback (VF) and the other with non-visual feedback (No-VF) about the results, with 50 subjects in each group. Then, each of these two groups were split into five subgroups: control (Cont), internal attentional focus on the arm (IntF), and three external attentional focus groups with a difference in distance of attentional focus – external focus on the dart (ExtF-D), external focus on the flight of a dart (ExtF-F), and external focus on the bull's-eye of the dartboard (ExtF-B subgroup). Consequently, there were 10 subjects in each group.

Learning conditions

The subjects of the VF groups practiced under normal visual conditions including visual feedback on the result of each throw trial. In the No-VF groups as soon as a participant released the dart, the experimenter who stood one meter away from the throw line (Figure 1, A) raised a 50 cm x 50 cm cardboard cut-out to occlude the view of the performance and prevent knowledge of the accuracy of dart throws (Figure 1, B). The subjects of both IntF subgroups were asked to: 1) feel the weight of the dart in their fingertips 2) bring the fingertips toward their ear while bending the elbow, and 3) feel the dart as it left the fingertips (Marchant, et al., 2007).

The subjects of the ExtF-D subgroups were required to: 1) take the dart; 2) bring the dart toward the wall behind them, and 3) throw the dart at the bull's-eye. There were only two instructions for the ExtF-F and ExtF-B subgroups. The first instructions were the same for both subgroups: "take the dart". In the second instructions, they were asked to adopt directly a distal focus of attention (movement effect) and "focus on the flight of the dart" (ExtF-F) or "focus on the bull's-eye" (ExtF-B). There were no attentional focus instructions for Cont subgroups.

The acquisition session

All the participants completed a total number of 36 trials of throwing a dart in 6 blocks with six trials in each block. The blocks of trials were interspersed with a rest interval for all the subgroups. The importance of a given attention focusing on the instruction was highlighted at the beginning of each six-trial block. After execution of each block, a participant was given the two following short verbal questions to check the attentional focusing of the

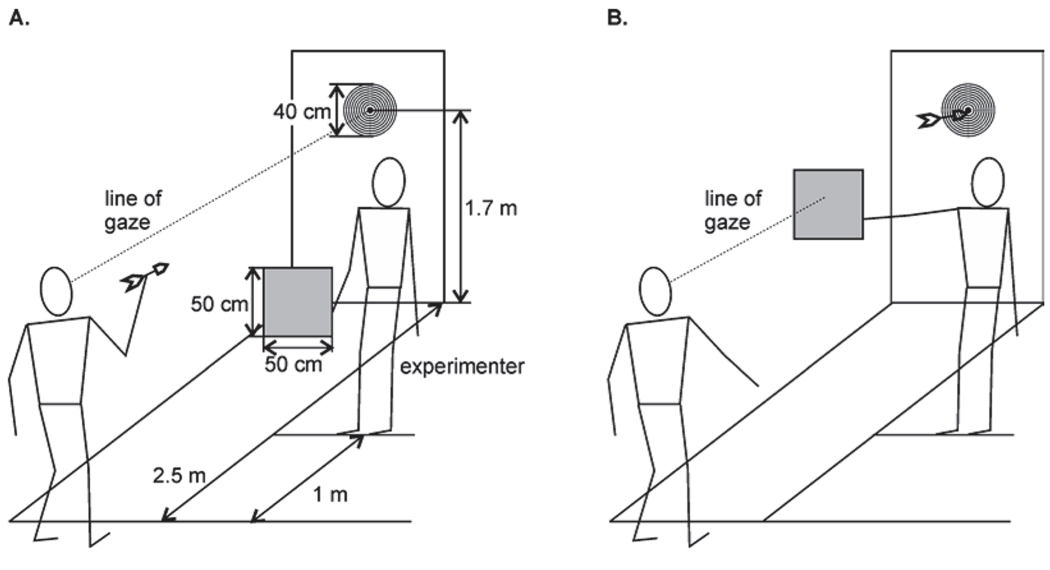

Figure 1. Scheme of the dart throwing task in acquisition phase, (A): before throw, (B): after throw.

subject while performing the dart throw: "Did you focus on the instructions given?"; and "What did you focus on?". However, for the Cont subgroups, the only question was "What did you think about during the execution of the throw"? All the answers were recorded using a tape recorder. The main goal of these questions was only to remind the participants that focusing attention on the requested instructions is important. After each throw, the experimenter recorded the accuracy score and removed the dart from the board.

Retention and transfer tests

One day after the acquisition session, the retention and transfer tests were performed. In both tests participants from all subgroups completed one block of six trials of throwing a dart. However, no attentional focus instruction was given.

The transfer test was performed 10 minutes after the retention one. In the transfer test, the participants were asked to throw the darts at the pendulum board. Before each trial the experimenter moved the hanging board to the starting position in which the bull's-eye was parallel to the ground. Then, he let the dartboard go. The participants were asked to throw the dart before the 4^{th} pendulum movement of the board to complete the task. They were told that if they threw the dart after the fourth pendulum movement, the score would be zero.

In the transfer test we were interested in examining the effect of the acquisition of dart throwing at a stable target when assisted by different attentional focus instructions accompanied by visual or no visual feedback on the result of the skill of a dart throw at a moving target, i.e. aiming performance in a variable environment.

Data analysis

The mean of the score of dart-throwing accuracy achieved in the given six-trial block presented the dependent variable. For the acquisition phase the accuracy scores were analyzed by a three-way ANOVA in 2 (VF vs. No-VF condition) x 5 (the attentional focus: IntF, ExtF-D, ExtF-F, ExtF-B, Cont) x 6 (trial blocks of practice, as the factor of the amount of practice), with repeated measures of the last factor. A one-way ANOVA was conducted to assess the average of accuracy scores in the warm-up phase to ensure that all the groups were not different at the beginning of practice.

The scores achieved in the retention and transfer tests were analyzed using a two-way ANOVA in 2 (groups: VF vs. No-VF) x 5 (the attentional focus sub-groups: IntF, ExtF-D, ExtF-F, ExtF-B, Cont). The Bonferroni corrections were performed for all adjustments. Also, the Bonferroni *post-hoc* test was performed where appropriate and if the ANOVAs were significant. The level of significance was set at .05 for all statistical tests.

Greenhouse-Geisser epsilon values were used to adjust the degrees of freedom in the ANOVAs with repeated measures to compensate for deviations from the assumption of sphericity. The data analyses were performed using the statistical software SPSS-21 (IBM, USA).

Results

Manipulation check

The analysis of responses to the first question indicated that all the participants in the internal and different external focus groups followed instructions as directed. However, a descriptive analysis of answers to the second question revealed that participants claimed that they adopted related-focus instructions through blocks of trials, respectively (90, 90, 93, 95, 95, and 95%). These findings indicated that participants in each group obtained particular focus instructions in line with the goal of study.

Throwing performance during the acquisition session

All the groups showed considerable improvement in dart throwing accuracy across the six blocks of six trials (Figures 2 and 3). The main effect of the trials was significant $F(4.74, 427.43)=11.860$, $p=.000$, $\eta p^2=.116$, demonstrating the improvement of participants through practice in both VF and No-VF groups. A *post-hoc* test revealed that in the VF group the participants had a better performance from the 2^{nd} to 6^{th} in contrast to the 1^{st} trial (Figure 2), while the participants in No-VF group had a better performance in the 6^{th} compared to the 1^{st} block of trials (Figure 2).

The main effect of visual feedback was significant $F(1, 90)=4.785$, $p=.031$, $\eta p^2=.050$, with the VF group showing more accurate scores than the No-VF group (Figure 3). In addition, the interaction of trials and attentional focus groups was significant, $F(18.99, 427.43)=2.132$, $p=.004$, $\eta p^2=.087$. The subsequent *post-hoc* tests demonstrated that

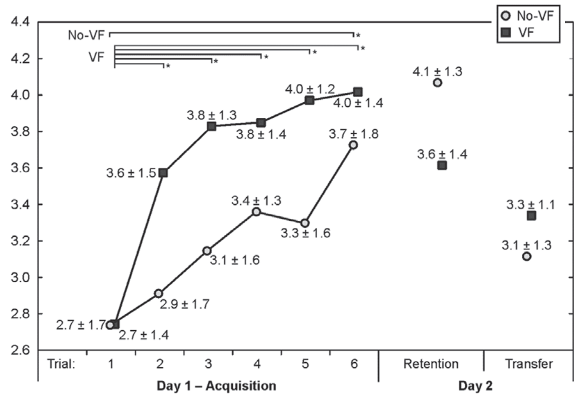

Figure 2. *The mean accuracy scores of throws across 6 blocks of 6 trials in the acquisition, retention and transfer for the visual feedback (VF) and non-visual feedback (No-VF) groups (p≤.05).*

VF group had a better performance than No-VF group in the 2nd, 3rd, and 5th blocks of trials (Figure 3). Also, the main effect of attentional focus instructions, $F(4, 90)=1.012$, $p=.406$, $\eta p^2=.043$, and the interactions of VF and attentional focus instructions, $F(4, 90)=.764$, $p=.551$, $\eta p^2=.033$, and VF and trials, $F(4.74, 427.43)=1.409$, $p=.222$, $\eta p^2=.015$, were not significant.

The type of attentional focus instructions showed that it is not a significant factor for the mean score of throwing accuracy (Figure 4). Also, no significant interaction effects of trials, the visual feedback condition and attentional focus were found.

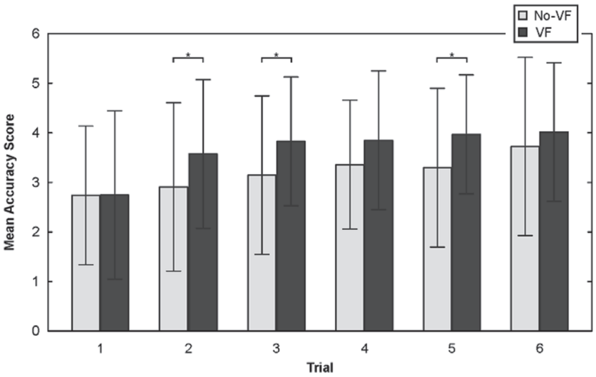

Figure 3. Comparison of the mean scores of throw accuracy for the visual feedback (VF) vs. non-visual feedback (No-VF) groups in the separate blocks of trials in practice. Error bars represent standard deviations (p≤.05).

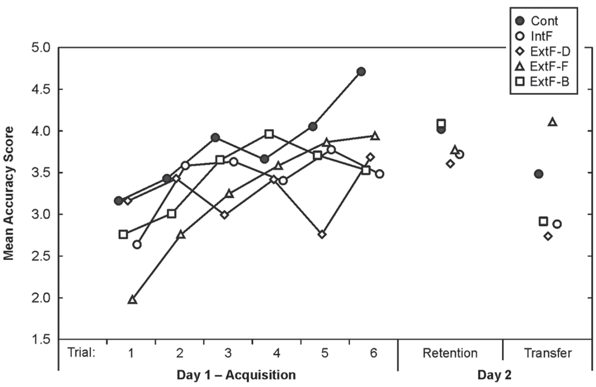

Figure 4. The mean scores of throw accuracy achieved in the control (Cont), internal focus (IntF), external focus on the dart (ExtF-D), external focus on the flight of a dart (ExtF-F) and external focus on the bull's-eye of the dartboard (ExtF-B) subgroups, regardless of type of visual feedback condition.

Performance in the retention test

The mean performance score for VF and No-VF groups, and specifically for the different attentional focus subgroups in the retention test is presented in Figures 2 and 4 (middle panel). The main effects of VF, $F(1, 90)=2.615$, $p=.109$, $\eta p^2=.028$, the attentional focus, $F(4, 90)=.420$, $p=.794$, $\eta p^2=.018$, and the interactions of VF and attentional focus groups, $F(4, 90)=1.174$, $p=.328$, $\eta p^2=.050$, failed to reach significance.

Performance in the transfer test

As can be seen in Figures 2 and 4 (right panel), the main effects of attentional focus subgroups, $F(4, 90)=4.727$, $p=.002$, $\eta p^2=.174$, was significant. The *post-hoc* test showed that the ExtF-F group was better than the other attentional focus and control groups. The main effects of VF, $F(1, 90)=.940$, $p=.335$, $\eta p^2=.010$, and the interactions of VF and attentional focus groups, $F(4, 90)=1.376$, $p=.249$, $\eta p^2=.058$, were not significant.

Discussion and conclusions

The aim of the study was to examine how the different visual vs. no-visual feedback on the performance results of novice learners during and after execution of a target task could affect the expected advantages of external over internal attentional focus instructions. In other words, we examined how visual feedback can moderate the relation between attentional focus instructions and motor performance/learning. The visual feedback reduction for the No-VF group consisted of preventing the vision from both the flight of the dart to the target for 60% of the distance of its flight, and also the dart landing point on the dartboard, i.e. no visual feedback on the result was available in each trial.

In the current study, the performance enhancement with visual feedback on the results illustrated more effective skill acquisition than non-visual feedback condition, with no dependency or interaction with the type of attentional focus instructions. These findings are in line with the results of Perkins-Ceccato et al. (2003) who used a golf putting skill. These results suggest that if visual feedback during a goal-directed movement skill is strongly limited by non-visual feedback about the results, the advantage of the external focus over the internal focus fades. Our results were not consistent with the study by Land et al. (2013) who found that beneficial effects of adopting an external focus of attention is not dependent on receiving visual information by accessing knowledge of results during and after executing a golf putting task. However, using within-subject group design (Land, et al., 2013) might be the cause for having different results from the present study.

Also, we examined the effects of external attentional focus on further locations in learning condition through retention and transfer tests in a variable but predictable environmental condition. Although particular attentional focus instructions in retention were not different from each other, the ExtF-F was the best attentional focus strategy in transfer test when participants threw the darts at a pendulum board which moved regularly. Our results for the ExtF-F group agreed with the results of previous studies (Abdollahipour, Bahram, Shafizadeh, & Khalaji, 2008; Land, Frank, & Schack, 2014; Landers, Wulf, Wallmann, & Guadagnoli, 2005; Poolton, Maxwell, Masters, & Raab, 2006; Totsika & Wulf, 2003; Wulf, Landers, Lewthwaite, & Töllner, 2009; Wulf & Su, 2007; Wulf, Töllner, & Shea, 2007), thus showing the advantage of external over internal attentional focus when subjects were faced with a more challenging task or condition. Also, our results are in line with the previous studies that demonstrated that the external cues should be divided between execution of the movement and environmental information (Shumway-Cook & Woollacott, 2007; Lohse, et al., 2014), and that there is an optimum limit for external focus of attention for novice performers in the golf putting task (e.g. Shafizadeh, Mcmorris, & Sproule, 2011; Wulf, et al., 2000, experiment 2). However, in contrast with the other studies (McKay & Wulf, 2012; McNevin, et al., 2003), increasing the distance of external focus as far as possible (ExtF-B) and close external focus (ExtF-D) were not more beneficial than internal focus for throwing darts at the pendulum dartboard (an unstable target). It is possible that object orientation in the environment affects visual processing strategies (Smeets, Brenner, De-Grave, & Cuijpers, 2002).

Interestingly, enhancement of accuracy scores during the practice phase under both VF (normal condition) and No-VF on the results in the present study is not in line with the suggested theories of motor control and learning which explain that if any of various sources of information is unavailable following a movement, no motor schema updating (learning) can occur (Mass, et al., 2008). Therefore, it can be pointed out that it is impossible for performers to not notice and therefore not alter their attentional focus to use biased or another source of information, especially proprioception and audition (in our study, the sound from a dart hitting the dartboard), when vision is unavailable (Wulf & Prinz, 2001; Trembly, 2010). Perhaps a shift in the use of sensory sources of other modalities and/or compensation for a lack of visual information by proprioceptive and auditory information met the demands of target task coordination. Nonetheless, the benefit of visual information on the results mostly at the beginning of the acquisition session indicates that the withdrawal of visual feedback on the performance results may not degrade the importance of visual information (in a target task) when available. These sensory-motor mechanisms could explain the similar tempo of increasing performance during practice conditions under both VF and No-VF on the performance results, and also no significant difference in performance of throwing the dart in both retention and transfer tests (between the two groups which were practicing under these two different visual feedback conditions). The other possible reason for the results is that when the advantage of one source of afferent information (e.g. vision) is not available, the brain may process other sources of afferent information which are not influenced by vision to certify performance accuracy (Toussaint, Robin, & Blandin, 2010). In other words, when there are actions but the sensory consequences cannot be observed, states decay at various rates, but uncertainty grows. Increased uncertainty encourages learning (Kording, Tenenbaum, & Shadmehr, 2007).

There were some limitations in the present study that could be a concern for future experiments. First, we suggest that the number of practicing trials should be increased to give a more precise information about the actual skill acquisition processes. It could be argued that limited number of practicing trials will be considered as "adaptation" rather than "learning" (Newell, Mayer-Kress, Hong, & Liu, 2009). Second, although using the questionnaire in the present study gave us an estimation about focusing of subjects on particular instructions, yet further information is needed to ensure that participants have been focusing on the given instructions. These methodological approaches can give us a better understanding for the generalizability of the present results.

In conclusion, this study demonstrated that visual feedback on the results can provide a benefit for acquisition of a target task temporarily during practice, in comparison to non-visual feedback on the results. However, the benefits of providing visual feedback on the results were not retained until the following day after practice when both groups received visual feedback on the performance result. The study suggests that the expected advantages of the external attentional focus instructions can be disrupted during acquisition of a target task when visual information are strongly reduced under non-visual feedback on the results. Therefore, the visual feedback on the results was shown to be possibly a more effective factor in acquisition of a target task in learners-beginners than attentional focus instructions. In addition, this study supported the advantages of external focus of attention (when it was shared between execution of the movement and environmental information) rather than internal focus of attention in a more challenging target task that supports *constrained action hypothesis* (McNevin, et al., 2003; Wulf, 2013; Wulf, McNevin, & Shea, 2001) in more challenging motor skills and environments. Hence, it seems that the optimized distance of external focus of attention may be variable with regard to stable or unstable targets. The findings of the present study can practically be used by teachers and coaches in a way that they should carefully provide the correct verbal instructions for learners in different stages of learning processes. Future studies should be conducted to examine the role of vision and attentional focus on motor learning in different types of motor skills.

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