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Disability and Rehabilitation

ISSN: 0963-8288 (Print) 1464-5165 (Online) Journal homepage: https://www.tandfonline.com/loi/idre20

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To cite this article: Reza Abdollahipour, William M. Land, Ana Cereser & Suzete Chiviacowsky (2019): External relative to internal attentional focus enhances motor performance and learning in visually impaired individuals, Disability and Rehabilitation

To link to this article: https://doi.org/10.1080/09638288.2019.1566408

Published online: 08 Feb 2019.

DISABILITY AND REHABILITATION
https://doi.org/10.1080/09638288.2019.1566408

ORIGINAL ARTICLE

External relative to internal attentional focus enhances motor performance and learning in visually impaired individuals

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ABSTRACT

Background: Research has demonstrated the advantages of an external relative to internal focus of attention for enhancing motor performance and learning across diverse tasks, contexts and populations. However, research has yet to examine whether this finding holds true for individuals who have a major visual impairment in discrete and locomotion-based continuous motor tasks.
Methods: In experiment 1, twenty-four visually impaired participants were asked to kick a soccer ball with their dominant foot to a target 7 meters away. Participants performed 10 trials within an internal focus (concentration on inside of the foot), external focus (concentration on the ball), and control (no focus instructions) conditions, in a counterbalanced order. In experiment 2, thirty-nine visually impaired adults were asked to ride a rehabilitation Pedalo for a distance of 7 meters. Participants were randomly assigned to either an internal focus (focus on the feet), external focus (focus on the platform), or control (no focus instructions) group. Retention and transfer tests were conducted on day 2.
Results: An external focus resulted in more accurate kicks and faster pedalo movement times compared to an internal focus.
Conclusions: These findings indicate that visual information does not mediate external focus benefits for motor performance and learning.

ARTICLE HISTORY
Received 31 July 2018
Revised 4 January 2019
Accepted 4 January 2019

KEYWORDS
Focus of attention; soccer; balance; visual impairment; performance; learning

➤ IMPLICATIONS FOR REHABILITATION

- Practitioners should use instructions that encourage visually impaired individuals who are going through rehabilitation to adopt an appropriate focus of attention for enhancing motor performance and learning of discrete or locomotion-based motor skills.
- Instructions that foster an external focus, relative to an internal focus, enhances performance of both discrete and continuous motor skills in individuals with visual impairment.

Introduction

According to a report from the World Health Organization (WHO), there are about 1.3 billion individuals with visual impairments worldwide [1]. Individuals with visual impairments are classified into two groups according to distance and near vision impairment. The distance visual impairment is divided into four subcategories such as mild, moderate, severe and blindness when presenting visual acuity is worse than 6/12, 6/18, 6/60, and 3/60, respectively. The near visual impairment is defined when visual acuity is worse than N6 or N8 at 40 cm with existing correction [2,3]. Importantly, poor visual acuity can have important consequences for motor performance and development of psychomotor reaction, spatial orientation, eye-muscle coordination, body awareness and equilibrium maintenance [4,5].

Vision has been shown to be useful for motor execution in both discrete (e.g., aiming, jumping) and continuous (e.g., walking) motor actions [6,7]. For example, studies have shown that vision is crucial for reaching optimal speed and accuracy in manual-aiming tasks [6,8]. In the initial phase of aiming actions, vision identifies direction of movement for goal-action coupling between the goal and limb movements. Also, vision is critical for final adjustments of parameters required for increasing precision of movement execution [9]. Moreover, vision plays a significant contribution in performance enhancement of a whole-body discrete action (e.g., jumping), regardless of attentional focus instructions [10]. Given the role of vision, visual impairments can have negative influences on the coupling between goals and movement in aiming actions. In continuous motor actions (e.g., walking), vision is also important for safety and navigating the environment [7,11]. Consequently, absence of vision can also negatively influence continuous motor actions such as locomotion-based motor skills [12].

When vision is not available, individuals with visual impairments use alternative strategies to overcome the difficulties in stability and navigating the environment [13]. Regardless of lack of vision or poor vision in individuals with visual impairments, research has reported potential differences in motor control between children with visual impairments and their peers with normal vision, as the first group has shown difficulties in calibrating sensory information [14]. Research has also suggested that individuals with visual impairments have reported deficits in

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cognitive function [15], which may influence motor performance. It should be noted that cognition and attention are interrelated, with a remarkable influence on each other [16]. Cognition refers to thought processes, which normally influences learning [17]. Attention is the allocation of concentration on specific information, and has been repeatedly linked to the efficiency of motor learning and performance [18]. Therefore, any impairments in sensorial or cognitive functioning may influence the effectiveness of focus of attention instructions, thereby impacting the learning process.

In motor learning studies, ample empirical evidence has demonstrated the advantages of instructions or feedback inducing an external relative to internal focus of attention for enhancing motor performance and learning across diverse tasks in healthy subjects with normal vision (see Wulf [19]). In particular, an external focus of attention is defined as the information that typically direct performer's focus of attention to intended movement effects such as the apparatus, implement, or target, whereas an internal focus of attention refers to information that direct a performer's focus of attention to the movements of the body, such as movement techniques [20]. For example, studies have shown that an external focus compared to an internal focus of attention enhances either or both motor performance and learning on a variety of discrete motor actions such as golf putting [21–23], soccer throw-in [24], dart throwing [25], basketball free shoots [26], tennis forehand stroke [27], throwing tennis balls at a target [28], catching tennis balls [29], and jumping [30]. Similarly, these advantages were found for various continuous motor actions such as maintaining balance on a stabilometer (Wulf et al. [20], Chiviacowsky et al. [31], McNevin et al. [32] Experiment 2), ski simulator (Wulf et al. [20] Experiment 1), swimming [33], and riding a pedalo [34,35].

Not only have healthy subjects been shown to benefit from an external compared to an internal focus of attention, but also some specific populations. For example, in children with attention deficit hyperactivity disorder, external focus instructions were found to be more beneficial for enhancing learning and accuracy of tossing tennis balls [36]. Similarly, children with intellectual disability were also benefitted by external focus instructions on a ball throwing task [37]. Finally, an external focus of attention has been shown to improve performance in individuals with Parkinson's disease [38,39].

While research has shown external focus is helpful for healthy subjects and certain populations (see above), this benefit was not observed in a population with visual impairments [40]. In a study by McNamara et al. [40], the authors asked children with moderate or profound visual impairments ($N = 18$, $M_{age} = 12.28 \pm 0.71$ years) to keep the balance on a stabilometer using either internal focus (i.e., focus on keeping your feet level) or external focus (i.e., focus on keeping the markers on the platform level) instructions. Participants in each moderate or profound visual impairments group performed two experimental trials in a counterbalanced order (i.e., one trial in each attentional focus condition), and the results suggested that the main effect of attentional focus instructions was not significant. However, the follow-up tests for the interaction of attentional focus and visual impairments groups showed that the external focus was better than internal focus instructions for children with moderate visual impairments. Despite the methodological concerns in this study (i.e., limited sample size and number of trials), it is possible that people with visual impairments have potentially developed different motor control strategies [5,14] relative to typical participants. That is, the mechanisms of attentional focus might operate differently, or not at all, and thus, external focus might not be helpful for individuals with profound visual impairments. Also, due to the impact of using preferred or familiar focus instructions on enhancing motor performance [41,42], it has been suggested that individuals with visual impairments would probably prefer to use an internal focus that promotes the use of introspective feedback (e.g., proprioception) rather than an external focus of attention due to limited access to exteroceptive feedback (e.g., vision and auditory) during their lifetime [40].

The purpose of the present study was to further examine the influence of attentional focus on motor performance and learning in individuals with severe visual impairments. Specifically, we examined the effect of attentional focus on both a discrete and continuous motor task as they use different feed-forward (used to control rapid discrete movements before process of any sensory information) and feedback motor control (used to control continuous movements and relies on sensory information from environment) systems, respectively. In the first experiment, we assessed the influence of attentional focus instructions on the performance of a discrete motor task (soccer kick) using a within-subject design. In the second experiment we examined the effects of attentional focus instructions on the learning of a continuous motor task (riding a pedalo) in visually impaired individuals using a between-subject design.

Experiment 1

In the first experiment we examined the effects of attentional focus instructions on motor performance of a discrete motor task (e.g., soccer kicks) in individuals with visual impairments.

Material and methods

Participants

Twenty-four adults (mean $age = 46.58 \pm 10.53$ years) from the association of individuals with visual impairments, Pelotas, Brazil, who did not have any previous experience with the task were recruited for this study. Participants had either acquired or congenital visual impairments, and were diagnosed as visual impairments according to the world health organization classification (Table 1). The levels of visual impairment were collected from the participants' record, and diagnosed by a certified medical doctor under the association of the Brazilian Federal Medical Council. An a priori power analysis indicated that 24 participants would be sufficient to identify significant differences in the dependent variables using repeated measurements within-subject design with a power (1 - β) of 0.80, effect size f of 0.27 ($\eta_\rho^2 = 0.07$), and an α of 0.05 [43]. Participants did not have any other physical or mental disabilities, according to the patient's record. They were given general information about the experiment; however, they were not provided information about the specific purpose of the study. The experimental procedures were approved by the university's institutional review board prior to beginning the experiments. Informed consent was obtained from each participant before taking part in the study.

Apparatus and task

The task required participants to kick a standard soccer ball (circumference: 69 cm; weight: 440 g) with the inside of their dominant foot toward a target. The task was performed indoors on a carpeted floor. The soccer ball was placed behind a line (100 × 3 cm), and was located a distance of 7 meters from the

Table 1. Experiment 1: Participants' characteristics.

Participant	Age	Gender	Etiology	Visual impairment duration	Pathology	Education level
1	51	F	C	–	Ca	complete primary education
2	55	F	C	–	Ca	incomplete elementary school
3	19	M	C	–	Ca	complete primary education
4	38	F	A	6 years	G	incomplete elementary school
5	33	M	C	–	MD	incomplete elementary school
6	47	M	A	6 years	U	incomplete elementary school
7	48	M	A	8 years	U	complete primary education
8	57	F	A	4 years	T	complete primary education
9	40	M	A	7 years	RD + Ca	incomplete elementary school
10	56	M	C	–	PR + Ca	incomplete elementary school
11	53	M	A	6 years	RD	incomplete higher education
12	33	M	C	–	RD	incomplete elementary school
13	39	F	A	5 years	G	incomplete higher education
14	59	M	A	8 years	G	complete primary education
15	55	F	A	2 years	G	incomplete higher education
16	56	M	A	5 years	Ca	incomplete elementary school
17	57	M	A	20 years	AWF	incomplete elementary school
18	52	F	A	8 years	U + Ca	complete higher education
19	35	F	A	4 years	K	incomplete elementary school
20	48	F	A	10 years	RD	complete primary education
21	42	F	A	4 years	HM	complete high school
22	51	F	A	2 years	DR	complete primary education
23	35	F	A	11 years	RP	incomplete elementary school
24	59	M	A	10 years	T	complete primary education

C: congenital; A: acquired; Ca: cataract; G: glaucoma; MD: macular dystrophy; U: uveitis; T: trauma; RD: retinal displacement; PR: pigmentary retinitis; AWF: accident with firearm; K: keratoconus; HM: high myopia; DR: diabetic retinopathy; T: toxoplasmosis.

target. The target area consisted of a yellow colored square (measuring 50 cm wide and 50 cm high) located in the middle of a premier steel soccer goal constructed with heavy-duty, rust-resistant steel (128 width, 55 height, depth 50 cm). Two additional target zones with the same-sized dimensions were hung to the left and right of the main target. The target zones were hung from the horizontal bar of the soccer goal, and were positioned 25 cm off the ground. Two points were awarded if the ball hit the central colored zone. One point was awarded if the ball hit one of the lateral zones to the left or right of the main target. 0 points were given if the ball did not hit any target (see Figure 1). Even though all participants were diagnosed with visual impairments, a mask (Sleep Mask, Prime Effects, Dunedin, FL) was used to cover participant's eyes to eliminate any possibility of receiving visual information, and to make the degree of visual impairment consistent across all individuals.

Procedure

To begin, the experimenter provided some basic information about the kicking task, and had participants complete the informed consent. Following, the participant's eyes were covered with a mask to occlude all vision. Participants were then positioned behind the start line, and given the opportunity to touch the ball with their hands. Next, participants were guided by the experimenter from the start line to the target area. The participant was able to detect the target location by touching it with their hands. Subsequently, they were guided back toward the start line and positioned behind the ball toward the target. The ball was given to the participants before each trial and asked to position the ball in front of them while staying behind the start line. The correct position of the ball behind the start line was checked by the experimenter before each trial. Finally, the participants were instructed to kick the ball towards the central target. This procedure was performed before kicking each ball. To become familiar with the task, participants performed one familiarization trial of kicking the ball toward the target. Participants completed 10 trials in each of the three attentional conditions: internal focus (i.e., concentrate on the inside of the foot), external focus (i.e., concentrate on the ball), and control (no focus instructions). The order of the conditions was counterbalanced across participants. Knowledge of results (i.e., score and direction of the kick) were provided after each trial.

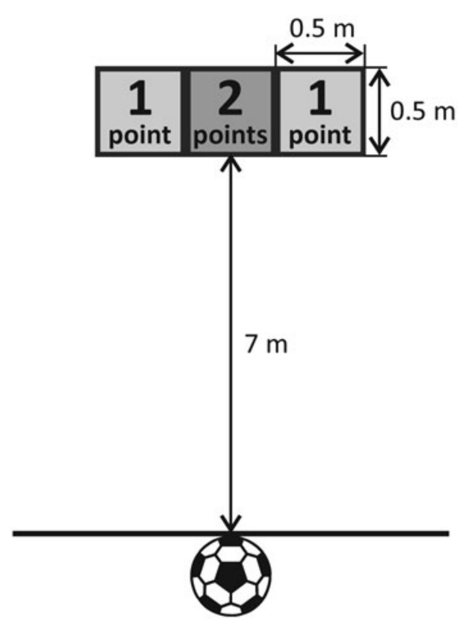

Figure 1. Schematic of Soccer kicking task.

Data analysis

Kicking performance was calculated as the sum of the accuracy scores obtained from the 10 trials per condition and served as the dependent variable. Preliminary analyses of the results identified violations to the assumptions of normality in the outcome variable due to outliers. As outliers were distributed across the

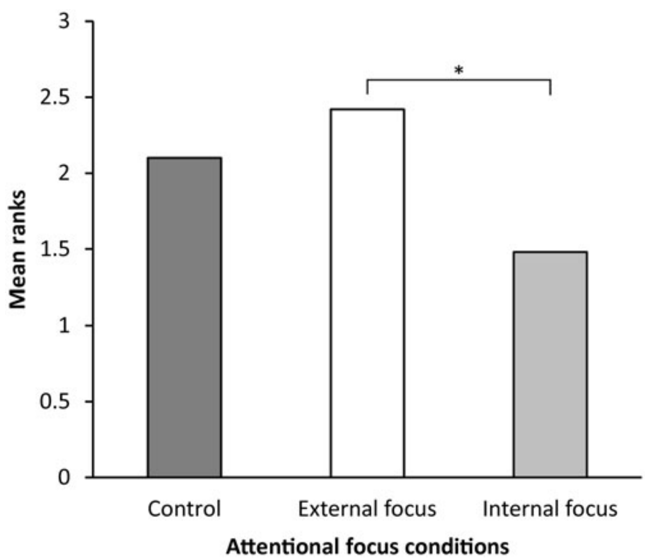

Figure 2. Mean ranks for attentional focus conditions. * $p < 0.01$

different focus conditions, and the current study was based on a within-subject design, excluding outliers was detrimental to statistical efficiency [44]. Therefore, Friedman and Dunn-Bonferroni post hoc tests were used to evaluate the differences in mean ranks (M_{Rank}) among attentional focus conditions. The effect sizes for non-parametric Friedman test was estimated using Kendall's *W (or* Kendall's coefficient of concordance), with values ranging from 0 (no relationship) to 1 (a perfect relationship) and higher (a strong relationship) [45]. The level of significance was set at 0.05. All analyses were performed using the IBM SPSS software (version 21.0; IBM, Armonk, NY).

Results

The results of the Friedman test showed a significant difference in mean ranks among control ($M_{Rank} = 2.10$), external ($M_{Rank} = 2.42$), and internal ($M_{Rank} = 1.48$) focus conditions, χ^2 (2, $N = 24$) = 11.667, $p = 0.003$, Kendall's $W = 0.243$, indicating relatively strong differences among the three focus conditions (Figure 2). The results of follow-up Dunn-Bonferroni tests indicated that kicking accuracy during the external focus condition was significantly better than the internal focus condition ($p = 0.003$, Kendall's $W = 0.408$). However, there was no significant difference between the control and either external focus ($p = 0.837$, Kendall's $W = 0.050$) or internal focus ($p = 0.091$, Kendall's $W = 0.189$) conditions.[1]

Discussion

The findings of experiment 1 indicated that the advantages of an external compared to an internal focus of attention could generalize to individuals with visual impairments for enhancing immediate performance on a discrete motor skill (e. g., soccer kick). Specifically, participants who adopted an external focus kicked the ball more accurately. This finding helps support the notion that external focus is beneficial for enhancing performance of a discrete motor skill under a feedforward motor control strategy. These results are in the line with previous work that has shown performance benefits for external focus over internal focus for discrete motor actions in healthy subjects. This finding also suggests the independence between the use of visual information and the mechanisms underlying attentional focus benefits [10,46,47]. That is, the external focus benefits were detected even when vision was completely removed before and during the performance of a discrete motor skill.

Experiment 2

In the second experiment we examined the effects of attentional focus instructions on motor performance and learning of a locomotion-based continuous motor task (e.g., riding a pedalo) in individuals with visual impairments.

Material and methods

Participants

Thirty-nine adults (mean age = 42.46 ± 12.82 years) from the association of individuals with visual impairments, Pelotas, Brazil, who did not have any previous experience with the task participated in the study. They were provided with general information about the study and the task, however, they were not aware of the specific purpose of the study. Participants had either an acquired or congenital visual impairments, and their visual impairments were also diagnosed by a certified medical doctor under the association of the Brazilian Federal Medical Council, according to the categories of world health organization (Table 2). Participants did not have any additional physical or mental disorders. An a priori power analysis indicated that 39 participants would be sufficient to identify a significant effect of the independent variable in a two-way repeated measure analysis of variance (ANOVA) with a power (1 - β) of 0.95, effect size f of 0.27 ($\eta_\rho^2 = 0.07$), and an α of 0.05 [43]. The study's protocol was approved by the university's institutional review board prior to data collection. Informed consent was obtained from all participants.

Apparatus and task

The task was to ride a Pedalo (Pedalo® Reha-Bar S, Holz-Hoerz GmbH, Münsingen, Germany) forward across a distance of 7 meters (see Figure 3). The Pedalo® Reha-Bar S is specifically designed for the purpose of physical therapy in senior citizens. The device has four telescopic support bars, which were adjusted to a height of 90 cm for all participants. Starting and ending lines were identified by two yellow tape lines (100 × 3 cm each). A stopwatch cell phone (Samsung Galaxy J7, Samsung, Seoul, South Korea) was used to record the movement time between the start and finish line. To ride the pedalo, the participants should stay on the pedals, hold the hands on the wooden bars and ride the device forward. All participants performed the task while wearing a visual occlusion mask (Sleep Mask, Prime Effects, Dunedin, FL) to eliminate the possibility of receiving visual information, and to create consistent visual impairment conditions across all participants.

Procedure

The experiment was carried out over two consecutive days. On day one, the experimenter provided general information about how to stand and ride the pedalo. Participants were then given the opportunity to perform the pedalo task one time as a familiarization trial. Next, participants were quasi randomly divided into three attentional focus groups including internal focus (i.e., focus on your feet) (6 congenital and 7 acquired vision deficiencies), external focus (i.e., focus on the platform) (7 congenital and 6 acquired vision deficiencies), and control (no focus instructions) (8 congenital and 5 acquired vision deficiencies). A quasi-random

Table 2. Experiment 2: Participants' characteristics.

Participant	Age	Gender	Etiology	Visual impairment duration	Pathology	Education level
External focus						
1	48	M	A	1 year	G + DR	incomplete higher education
2	57	M	A	7 years	PR + Ca	incomplete elementary school
3	56	M	C	–	Ca	incomplete elementary school
4	51	F	C	–	Ca	complete primary education
5	46	F	A	1 year	G + HM	incomplete elementary school
6	49	M	C	–	G + RD	incomplete elementary school
7	29	M	A	2 years	G	incomplete elementary school
8	59	M	C	–	PR	complete primary education
9	44	F	A	3 years	U	incomplete elementary school
10	45	F	C	–	Ca	complete primary education
11	30	F	C	–	CM	complete primary education
12	23	F	C	–	G	complete high school
13	60	M	A	10 years	G	complete primary education
Internal focus						
14	40	M	A	7 years	RD + Ca	incomplete elementary school
15	49	M	A	8 years	U + G	complete primary education
16	57	M	A	7 years	G	complete primary education
17	55	F	A	2 years	DR	incomplete elementary school
18	53	M	A	3 years	RD	incomplete higher education
19	21	F	A	4 years	ONI	complete primary education
20	52	M	C	–	HM	complete high school
21	39	F	A	10 years	DR + G	complete primary education
22	23	F	C	–	G	incomplete high school
23	38	F	C	–	SMC	incomplete elementary school
24	30	M	C	–	T	incomplete high school
25	31	F	C	–	CM	incomplete elementary school
26	25	F	C	–	T + HM	incomplete elementary school
Control						
27	56	F	C	–	Ca	incomplete elementary school
28	52	M	C	–	Ca	incomplete elementary school
29	20	F	C	–	G + RD	complete high school
30	39	F	C	–	G	complete high school
31	43	F	A	8 years	G	complete high school
32	60	F	C	–	K	incomplete elementary school
33	31	F	C	–	Ca	incomplete elementary school
34	18	M	C	–	Ca	complete primary education
35	37	F	A	2 years	HM	incomplete elementary school
36	49	F	A	5 years	DR	incomplete elementary school
37	49	M	A	3 years	PR	incomplete elementary school
38	33	M	C	–	RD	incomplete elementary school
39	59	M	A	5 years	T	complete primary education

C: congenital; A: acquired; Ca: cataract; G: glaucoma; MD: macular dystrophy; U: uveitis; T: trauma; RD: retinal displacement; PR: pigmentary retinitis; AWF: accident with firearm; K: keratoconus; HM: high myopia; DR: diabetic retinopathy; T: toxoplasmosis; CM: congenital malformation; ONI: optic nerve injury; SMC: scar of macular chorioretinitis.

Figure 3. Pedalo® Reha-Bar S.

procedure was selected to maintain equality in the level of visual impairment for each group according to the aetiology of visual deficiencies. All participants performed 20 practice trials with the assigned attentional focus instructions. Attentional focus instructions were given before each block of 5 trials. On day 2, a retention and two transfer tests were conducted. Each test consisted of 6 trials. In the retention test, participants were required to perform the task. No additional attentional focus instructions were provided in the retention test. In the first transfer test, participants were asked to ride the pedalo forward as fast as possible (under speed pressure). After a five-minute rest interval, the second transfer test was conducted in which participants were asked to ride the pedalo backwards as fast as possible [35].

To determine adherence of participants to the instructions in the external and internal focus groups, as well as understand what participants focused on in the control group, they were asked to fill out a manipulation check after finishing the practice trials on day one. Specifically, participants were asked to respond to the following question: "what did you focus on while performing the task"? The participants' verbal responses were recorded and then written down by the experimenter and transferred to the answer sheet.

Data analysis

In the present task, the outcome variable was calculated as the time it took to ride the pedalo from the start line to the finish line. During the practice phase, the average of the 5 trials across the 4 blocks was used as the dependent variable. In the retention and transfer phases, the averages of all 6 trials were utilized as the dependent variable. In the practice phase, data were analysed in a 3 (groups) x 4 (blocks) ANOVA, with repeated measures on the last factor. A separate one-way ANOVA was used to identify any possible significant differences between attentional focus groups in the retention and transfer phases. The Bonferroni post-hoc test was used for all subsequent data analyses. Estimates of effect size were quantified by using two measures. First, partial eta squared (η_ρ^2) was employed where $\eta_\rho^2 = 0.01$, 0.06, and 0.14 were estimated for a small, moderate, or large effect, respectively. Next, Cohen's d was utilized as a measure of difference between group means. The evaluation of Cohen's d corresponded to low ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) effects [48,49]. All analyses were performed using the IBM SPSS software (version 21.0; IBM, Armonk, NY).

Results

In the practice phase, the main effect of groups was significant, $F(2, 36) = 6.137$, $p = 0.005$, $\eta_\rho^2 = 0.254$. The *post-hoc* tests revealed that the movement time in the external focus group ($M = 6.47 \pm 1.88$) was faster than the internal focus group ($M = 10.03 \pm 3.87$, $p = 0.004$, $d = 1.170$). There were no significant differences between the control group ($M = 8.11 \pm 2.91$) and either external focus ($p = 0.346$, $d = 0.670$) or internal focus ($p = 0.202$, $d = 0.560$) groups. The main effect of blocks was also significant, $F(1.45, 52.45) = 50.837$, $p < 0.001$, $\eta_\rho^2 = 0.585$. *Post-hoc* tests revealed that the participants had a faster movement time in the 4th block compared to the 1st, 2nd, and 3rd blocks, in the 3rd block relative to the 1st, and 2nd blocks, and in the 2nd block compared to the 1st block. The interaction of groups and blocks was not significant, $F(2.91, 52.45) = 2.035$, $p = 0.122$, $\eta_\rho^2 = 0.102$, (see Figure 4).

On day 2, the results of the retention test indicated that there were significant differences between attentional focus groups, $F(2, 38) = 7.591$, $p = 0.002$, $\eta_\rho^2 = 0.297$. *Post-hoc* tests showed that the participants in the external focus group ($M = 5.42 \pm 1.21$) had a faster movement time than the internal focus group ($M = 8.64 \pm 3.29$, $p = 0.002$, $d = 1.299$). Also, the participants in the control group ($M = 6.40 \pm 1.32$) were faster than the internal focus group ($p = 0.036$, $d = 0.893$). There was no significant difference in the movement time between the external focus group and the control group ($p = 0.765$, $d = 0.773$).

Also, the results of transfer 1 for riding pedalo forward under speed pressure indicated that there were significant differences between groups, $F(2, 38) = 6.775$, $p = 0.003$, $\eta_\rho^2 = 0.273$). *Post-hoc* tests showed that the participants in the external focus group ($M = 4.78 \pm 1.13$) had a faster movement time than the internal focus group ($M = 7.75 \pm 3.02$, $p = 0.002$, $d = 1.302$). There was no significant difference in the movement time between the control group ($M = 5.97 \pm 1.56$) and either the external focus group ($p = 0.450$, $d = 0.873$) or the internal focus group ($p = 0.106$, $d = 0.740$).

Moreover, the results of transfer 2 for riding the pedalo backwards under speed pressure indicated that there was significant differences between groups, $F(2, 38) = 10.060$, $p < 0.001$, $\eta_\rho^2 = 0.359$. *Post-hoc* tests showed that the participants in the external focus group ($M = 7.34 \pm 1.64$) had a faster movement time than the internal focus group ($M = 11.74 \pm 3.16$, $p < 0.001$, $d = 1.747$). Also, the participants in the control group ($M = 9.02 \pm 2.53$) were faster than the internal focus group ($p = 0.028$, $d = 0.950$). There was no significant difference in the movement time between the external focus and the control groups ($p = 0.293$, $d = 0.788$).

Manipulation checks

The participants' responses in different attentional focus groups are presented in Table 3. These responses indicated that a high number of participants in both the internal focus group (92.3%) and the external focus group (76.9%) adopted the assigned attentional focus instructions. In the control group, the majority of participants used either external (38.6%) or internal (38.5%) focus strategies for riding the pedalo forward.

Discussion

The findings from experiment 2 indicated that the advantages of an external focus also extend to a locomotion-based continuous motor skill (e.g., riding a pedalo) for individuals with visual impairments. Not only were the benefits of an external focus evident

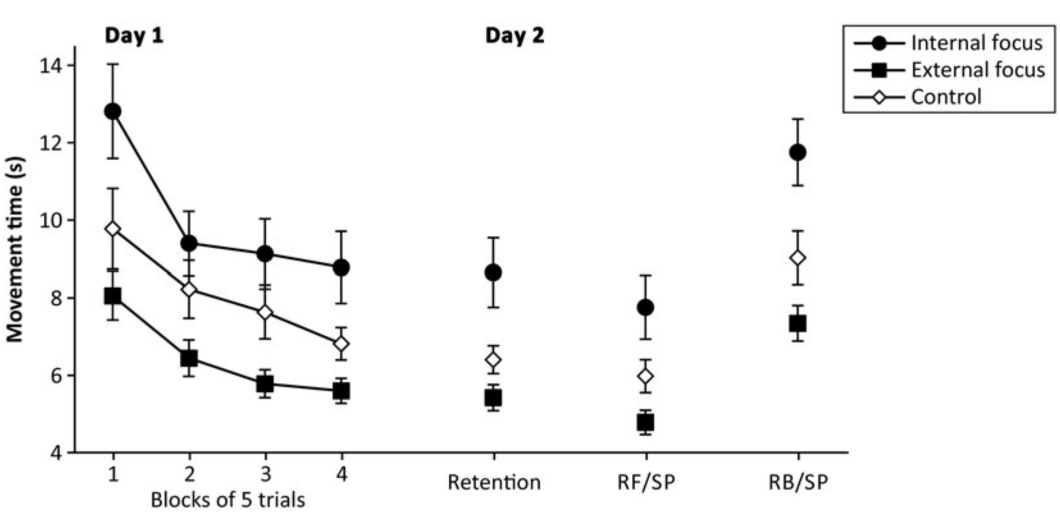

Figure 4. Performances of the internal focus, external focus, and control groups across the practice (day 1), retention, and two transfer tests including riding forward under speed pressure (RF/SP), and riding backward under speed pressure (RB/SP) (day 2). Error bars represent standard errors.

Table 3. The participants' responses in the different attentional focus groups.

	Attentional focus conditions		
	Internal (%)	External (%)	Control (%)
Reported external foci			
Pedal		76.9	30.7
Floor			7.7
Ceiling			
On the flight			
Total	0	76.9	38.4
Reported internal foci			
Feet/Legs	76.9		15.4
Feet & arm	7.7		
Arms			15.4
Force	7.7		
How many steps I need			7.7
Total	92.3	0	38.5
Reported other foci			
That I could do the task	7.7		
Balance		7.7	7.7
Time		7.7	15.4
Arrival		7.7	
Total	7.7	23.1	23.1

immediately during the practice phase on day 1, but more importantly, individuals with visual impairments also displayed benefits to motor learning due to an external focus of attention. Particularly, participants who adopted an external focus performed significantly faster during the retention and transfer phases on day 2. Therefore, external focus instructions can prove beneficial for learning and performance on continuous motor actions that are under a feedback motor control strategy for individuals with visual impairments.

General discussion

The findings from experiment 1 and 2 showed that the advantages of an external focus generalize to individuals with visual impairments across both discrete (e.g., kicking soccer ball at a target) and locomotion-based continuous (e.g., riding a pedalo) motor skills. Findings from the present study further highlight the independency of the mechanisms underlying external focus benefits from task characteristics and the role of vision in individuals with visual impairments. To our knowledge, these findings are the first to show the beneficial effects of external relative to internal focus of attention for motor performance and learning in individuals with severe visual impairments.

Our findings are in line with previous research indicating the advantages of external over internal focus of attention in healthy subjects (see Wulf [19]), in specific populations such as children with attention deficit hyperactivity disorder [36], children with intellectual disability [37], and individuals with Parkinson's disease [38,39]. However, our performance results are in contrast to a recent study [40] that reported children with profound visual impairments could not benefit from external focus instructions for optimizing motor performance on a stabilometer balance task. Possible explanations for these contradictory findings may be the higher statistical power, increased number of trials, and different age range of participants in our study. A Gpower analysis with a power (1 - β) of 0.80, medium effect size of 0.27 ($\eta_{\rho}^{2} = 0.07$), and an α of 0.05 shows that a minimum of 30 participants are considered necessary for detecting a significant effect of the independent variable (e.g., attentional focus instructions) for a 2 (groups: moderate vs. profound visual impairments) x 2 (trials: internal or external focus) mixed-model between-within-subject design [43]. In addition, a small number of trials (e.g., 2 trials) may possibly limit the ability of children with visual impairments to adopt the assigned instructions [40]. In fact, while several studies have found benefits of external relative to internal focus on motor performance and learning in children [27,34,36,37,50,51], other studies have reported they may have difficulties in follow specific focus of attention instructions [52,53]. These differences may have resulted in the different findings, with our experiments revealing the advantages of external focus over internal focus for individuals with visual impairments in both discrete and continuous motor tasks. Therefore, we suggest that these methodological aspects be carefully considered for future studies.

The findings of the current study also shed light on the mechanisms that underlie the beneficial effects of external focus of attention. Previous research studies have shown the advantages of external compared to the internal focus of attention are independent of vision in discrete motor actions [10,46,47]. The current results corroborate the independency of external focus benefits from vision not only for discrete motor actions (experiment 1), but also for locomotion-based continuous motor actions that usually are highly dependent on visual information (experiment 2). To our knowledge, the results of experiment 2 is the first to indicate that vision does not mediate the beneficial effects of the external compared to the internal focus instructions in continuous motor actions. Therefore, according to the findings of previous studies [10,46,47] and the current study, vision does not mediate the beneficial effects of external focus of attention in motor tasks that are under either feedforward or feedback motor control. Consequently, the performance differences associated with attentional focus seems to have no relation with constraining visual information during an internal focus, nor enrichment of picking up visual information during an external focus [54,55].

A plausible account of attentional focus effects that does not rely on the use of visual information is given by the constrained action hypothesis [56,57]. As stated by constrained action hypothesis, an internal focus of attention constrains execution of motor actions by disrupting the automatic motor control system. Whereas, an external focus of attention is the best cognitive strategy for optimizing automatic control processes with consequences for enhancing the execution of motor actions. In other words, internal focus takes actions which are proceduralized and controls them via conscious controlled processing, whereas external focus allows tasks to be performed more automatically because it utilizes more proceduralized rather than controlled processing. Also, an external focus compared to an internal focus may lead to better performance and learning outcome via effective neural connections across specific brain regions that are responsible for the task [58,59], which may result in increasing task-focus or goal-action coupling [50]. In other words, an optimal attentional focus (external focus) promotes functional connectivity among task-related neural networks, facilitating automatic motor control processing, causing coupling of goal and action with positive consequences in performance outcomes. Neurological findings have also suggested that enhancement in motor efficiency while execution of an action with an external focus of attention is probably due to the alteration in intracortical inhibitory circuits [58].

Thus, it is more likely that the observed differences in discrete and continuous motor actions between the internal or external focus conditions are related to cognitive mechanisms [16], which enhances task focus or goal-action coupling [50,59] or produces effective motor coordination [25], rather than dependency on visual information [10, 46].

From a practical perspective, the results of the current study suggest that providing appropriate external focus instructions for individuals with visual impairments who typically do not use vision or have limited access to visual information might be more useful than internal focus instructions for enhancing motor performance and learning of discrete and continuous motor actions. As such, clinicians who are interested in facilitating motor performance and learning of visually impaired individuals with difficulties in balance [60], or orientation and mobility [61], could utilize external focus instructions during rehabilitation settings when operating with assistive devices. This may in turn help visually impaired individuals to develop their perceptual processing capabilities, which ultimately impact their independence and quality of life.

Limitations and implications for the future research

Post-performance interviews regarding what participants focused on after performing the motor task in each attentional focus condition could be helpful for researchers to understand more about the actual thought processes of participants when executing a task. Specifically, in the control group/condition this method would help researchers to find out the underlying reasons for not finding significant differences between control and external focus instructions. We did not use post-performance interviews in the first experiment of this study, which limits our understanding of participants' thought process in each attentional focus condition. Yet, the results of the questionnaire in the second experiment found that in the control group, the attentional focus of participants is somewhat divided internally and externally. That is, not providing any particular focus instruction is not the best for learning, as visually impaired individuals may partially concentrate on body related information that induces an internal attentional focus.

In the current study, a mask was used to cover participant's eyes to keep the level of visual information consistent across all participants/groups. In future studies, it would be interesting to examine the effects of attentional focus instructions on visually impaired individuals without using a mask to understand the progress of enhancement in performance and learning of motor skills individually or in a specific visually impaired classification. Also, it would be of interest to examine differences in visual impairments, duration of impairment, and type and severity of visual field loss with respect to the benefits of adopting an external focus during skill acquisition. Such studies would further illuminate the impact that focus of attention instructions can have on facilitating motor learning and performance in individuals with visual impairment.

Disclosure statement

The authors report no conflicts of interest.

Note

1. An alternative analysis of data was conducted when all data were logarithmically transformed and the distribution of data was normalized [42]. The results from the normalized data was the same as the non-parametric results. Specifically, the results of a one-way ANOVA with repeated measurements on all focus conditions revealed that the main effect of focus conditions was significant, $F(2, 46) = 12.160$, $p < 0.001$, $\eta_\rho^2 = 0.346$. *Post-hoc* analysis showed that the kicking accuracy in the external focus condition ($M = 0.85 \pm 0.14$) was significantly higher than in the internal focus condition ($M = 0.65 \pm 0.24$, $p < 0.001$, $d = 0.988$). Also, performance of control condition ($M = 0.79 \pm 0.17$) was significantly better than the internal focus condition ($p = 0.014$, $d = 0.682$). There was no significant difference between the control and external focus conditions ($p = 0.245$, $d = 0.398$).

Funding

This study was financially supported by Czech Science Foundation under grant GAČR 18-16130S.

References

[1] World Health Organization. Blindness and visual impairment 2018. Available from: http://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment
[2] Bourne RRA, Flaxman SR, Braithwaite T, et al. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. Lancet Glob Health. 2017;5(9):e888–e897.
[3] Fricke TR, Tahhan N, Resnikoff S, et al. Global prevalence of presbyopia and vision impairment from uncorrected presbyopia: systematic review, meta-analysis, and modelling. Ophthalmology. 2018;125(10):1492–1499.
[4] Chokron S, Dutton GN. Impact of cerebral visual impairments on motor skills: implications for developmental coordination disorders. Front Psychol. 2016;7:1471.
[5] Juodzbaliene V, Muckus K. The influence of the degree of visual impairment on psychomotor reaction and equilibrium maintenance of adolescents. Medicina (Kaunas). 2006;42(1):49–56.
[6] Elliott D, Pollock BJ, Lyons J, et al. Intermittent vision and discrete manual aiming. Percept Motor Skills. 1995;80(3 Pt 2):1203–1213.
[7] Guidice NA, Legge GE. Blind navigation and the role of technology. In: Helal A, Mokhtari M, Abdulrazak B, editors. Engineering handbook of smart technology for aging, disability, and independence. Hoboken (NJ): Wiley; 2008. p. 479–500.
[8] Proteau L. Sensory integration in the learning of an aiming task. Can J Exp Psychol. 1995;49(1):113–120.
[9] Helsen WF, Elliott D, Starkes JL, et al. Coupling of eye, finger, elbow, and shoulder movements during manual aiming. J Motor Behav. 2000;32(3):241–248.
[10] Abdollahipour R, Psotta R, Land WM. The influence of attentional focus instructions and vision on jump height performance. Res Q Exerc Sport. 2016;87(4):408–413.
[11] Soong GP, Lovie-Kitchin JE, Brown B. Does mobility performance of visually impaired adults improve immediately after orientation and mobility training? Optom Vis Sci. 2001;78(9):657–666.
[12] Zhao H, Warren WH. On-line and model-based approaches to the visual control of action. Vision Res. 2015;110(Part B):190–202.
[13] Hallemans A, Ortibus E, Meire F, et al. Low vision affects dynamic stability of gait. Gait Posture. 2010;32(4):547–551.
[14] Reimer AM, Cox RFA, Boonstra NF, et al. Effect of visual impairment on goal-directed aiming movements in children. Dev Med Child Neurol. 2008;50(10):778–783.
[15] Chen SP, Bhattacharya J, Pershing S. Association of vision loss with cognition in older adults. JAMA Ophtalmol. 2017;135(9):963–970.

[16] Galotti KM. Cognitive psychology: in and out of the laboratory. 5th ed. Los Angeles (CA): SAGE; 2015.

[17] Lee TD, Swinnen SP, Serrien DJ. Cognitive effort and motor learning. Quest. 1994;46(3):328–344.

[18] Wulf G. Attention and motor skill learning. Champaign (IL): Human Kinetics; 2007.

[19] Wulf G. Attentional focus and motor learning: a review of 15 years. Int Rev Sport Exerc Psychol. 2013;6(1): 77–104.

[20] Wulf G, Höß M, Prinz W. Instructions for motor learning: differential effects of internal versus external focus of attention. J Motor Behav. 1998;30(2):169–179.

[21] An J, Wulf G, Kim S. Increased carry distance and X-factor stretch in golf through an external focus of attention. J Mot Learn Dev. 2013;1(1):2–11.

[22] Christina B, Alpenfels E. Influence of attentional focus on learning a swing path change. Int J Golf Sci. 2014;3(1): 35–49.

[23] Land WM, Frank C, Schack T. The influence of attentional focus on the development of skill representation in a complex action. Psychol Sport Exerc. 2014;15(1):30–38.

[24] Wulf G, Chiviacowsky S, Schiller E, et al. Frequent external-focus feedback enhances motor learning. Front Psychol. 2010;1:190.

[25] Lohse KR, Jones M, Healy AF, et al. The role of attention in motor control. J Exp Psychol Gen. 2014;143(2):930–948.

[26] Al-Abood SA, Bennett SJ, Hernandez FM, et al. Effect of verbal instructions and image size on visual search strategies in basketball free throw shooting. J Sports Sci. 2002;20(3): 271–278.

[27] Hadler R, Chiviacowsky S, Wulf G, et al. Children's learning of tennis skills is facilitated by external focus instructions. Motriz: Rev Educ Fis. 2014;20(4):418–422.

[28] Wulf G, Chiviacowsky S, Drews R. External focus and autonomy support: two important factors in motor learning have additive benefits. Hum Mov Sci. 2015;40:176–184.

[29] Abdollahipour R, Psotta R. Is an external focus of attention more beneficial than an internal focus to ball catching in children? Kinesiology. 2017;49(2):235–241.

[30] Wulf G, Dufek J. Increased jump height with an external focus due to enhanced lower extremity joint kinetics. J Motor Behav. 2009;41(5):401–409.

[31] Chiviacowsky S, Wulf G, Wally R. An external focus of attention enhances balance learning in older adults. Gait Posture. 2010;32(4):572–575.

[32] McNevin NH, Shea CH, Wulf G. Increasing the distance of an external focus of attention enhances learning. Psychol Res. 2003;67(1):22–29.

[33] Freudenheim AM, Wulf G, Madureira F, et al. An external focus of attention results in greater swimming speed. Int J Sports Sci Coach. 2010;5(4):533–542.

[34] Flôres F, Schild J, Chiviacowsky S. Benefits of external focus instructions on the learning of a balance task in children of different ages. Int J Sport Psychol. 2015;46(4): 311–320.

[35] Totsika V, Wulf G. The influence of external and internal foci of attention on transfer to novel situations and skills. Res Q Exerc Sport. 2003;74(2):220–232.

[36] Saemi E, Porter J, Wulf G, et al. Adopting an external focus of attention facilitates motor learning in children with attention deficit hyperactivity disorder. Kinesiology. 2013; 45(2):179–185.

[37] Chiviacowsky S, Wulf G, Ávila LTG. An external focus of attention enhances motor learning in children with intellectual disabilities. J Intellect Disabil Res. 2013;57(7): 627–634.

[38] Landers M, Wulf G, Wallmann H, et al. An external focus of attention attenuates balance impairment in patients with Parkinson's disease who have a fall history. Physiotherapy. 2005;91(3):152–158.

[39] Wulf G, Landers M, Lewthwaite R, et al. External focus instructions reduce postural instability in individuals with Parkinson disease. Phys Ther. 2009;89(2):162–168.

[40] McNamara SWT, Becker KA, Silliman-French LM. The differential effects of attentional focus in children with moderate and profound visual impairments. Front Psychol. 2017;8: 1804.

[41] Maurer H, Munzert J. Influence of attentional focus on skilled motor performance: performance decrement under unfamiliar focus conditions. Hum Mov Sci. 2013;32(4): 730–740.

[42] Weiss SM, Reber AS, Owen DR. The locus of focus: the effect of switching from a preferred to a non-preferred focus of attention. J Sports Sci. 2008;26(10):1049–1057.

[43] Faul F, Erdfelder E. GPOWER: A priori, post-hoc, and compromise power analyses for MS-DOS [Computer program]. 1992.

[44] Csibra G, Hernik M, Mascaro M, et al. Statistical treatment of looking-time data. Dev Psychol. 2016;52(4):521–536.

[45] Field A. Discovering statistics using SPSS. 3rd ed. London: SAGE; 2009.

[46] Land WM, Tenenbaum G, Ward P, et al. Examination of visual information as a mediator of external focus benefits. J Sport Exerc Psych. 2013;35(3):250–259.

[47] Sherwood DE, Lohse KR, Healy AF. Judging joint angles and movement outcome: shifting the focus of attention in dart-throwing. J Exp Psychol Hum Percept Perform. 2014; 40(5):1903–1914.

[48] Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. New York (NY): Academic Press; 1988.

[49] Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for *t*-tests and ANOVAs. Front Psychol. 2013;4:863.

[50] Abdollahipour R, Palomo Nieto M, Psotta R, et al. External focus of attention and autonomy support have additive benefits for motor performance in children. Psychol Sport Exerc. 2017;32:17–24.

[51] Palmer KK, Matsuyama AL, Irwin JM, et al. The effect of attentional focus cues on object control performance in elementary children. Phys Educ Sport Pedagogy. 2017; 22(6):580–588.

[52] Emanuel M, Jarus T, Bart O. Effect of focus of attention and age on motor acquisition, retention, and transfer: a randomized trial. Phys Ther. 2008;88(2):251–260.

[53] Perreault ME, French KE. Differences in children's thinking and learning during attentional focus instruction. Hum Mov Sci. 2016;45:154–160.

[54] Hodges NJ, Ford P. Skillful attending, looking and thinking. Beweg Train. 2007;1:23–24.

[55] Maurer H, Zentgraf K. On the how and why of the external focus learning advantage. Beweg Train. 2007;1:31–32.

[56] Wulf G, McNevin N, Shea CH. The automaticity of complex motor skill learning as a function of attentional focus. Q J Exp Psychol A. 2001;54(4):1143–1154.

[57] Wulf G, Shea C, Park J-H. Attention and motor performance: preferences for and advantages of an external focus. Res Q Exerc Sport. 2001;72(4):335–344.

[58] Kuhn YA, Keller M, Ruffieux J, et al. Adopting an external focus of attention alters intracortical inhibition within the primary motor cortex. Acta Physiol. 2017;220(2):289–299.

[59] Wulf G, Lewthwaite R. Optimizing performance through intrinsic motivation and attention for learning: the OPTIMAL theory of motor learning. Psychon Bull Rev. 2016;23(5):1382–1414.

[60] Jeon BJ, Cha TH. The effects of balance of low vision patients on activities of daily living. J Phys Ther Sci. 2013;25(6):693–696.

[61] Zijlstra GAR, Ballemans J, Kempen GIJM. Orientation and mobility training for adults with low vision: a new standardized approach. Clin Rehabil. 2013;27(1):3–18.