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The Distance Effect and Dual Task on Attentional Focus Cues During a Bimanual Task

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Motor performance has been shown to be superior when focusing on a physically farther environmental cue (external focus-far, EF-far) instead of a cue proximal to the body (EF-near). However, little is known about whether these foci affect bimanual tasks. Further, the effect of visual information on attentional focus is unclear. In the present study, healthy young participants were assigned to one of the internal focus (IF; $n = 17$), EF-far ($n = 17$), or EF-near ($n = 17$) groups and completed a tracking task on one day and two dual tasks on another day. During the dual-task tests, participants responded to auditory or visual stimuli while performing the primary tracking task. Results showed that both EF groups outperformed the IF group. Our results revealed that the EF groups improved in movement time and error, but the IF group did not improve in errors across the experiment. No distance effect was found. Also, the EF benefits over IF did not appear until later blocks of trials. Regarding the effect of vision, the distance effect was evident only during the auditory dual task condition, but not during the visual dual task condition when the primary task was distracted by the visual secondary task.

Keywords: motor behavior, the constrained action hypothesis, distal effect

Numerous research studies have shown that a cue that directs one's attention to their body movement (i.e., internal focus, IF) is suboptimal in motor performance and learning (Chua et al., 2021; Wulf, 2013) compared with a cue that directs their attention to an intended effect on the environment (i.e., external focus, EF). This EF benefit over IF has been replicated in various tasks, including skills typically investigated in the laboratory (e.g., manual tracking, aiming, paced reciprocal tapping, position matching, force matching/producing, and rotary pursuit tasks; Duke et al., 2011; Kuhn et al., 2017, 2021; Porter & Anton, 2011; Sakurada et al., 2019; Schlesinger et al., 2013; Yamada, Kuznetsov, et al., 2021) and more realistic complex skills (e.g., dart throwing, balance, golf,

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volleyball, basketball shooting, muscular strength or endurance task, sprint, and agility; Lohse et al., 2010; McNevin et al., 2003; Porter, Nolan, et al., 2010; Porter, Ostrowski, et al., 2010; Zachry et al., 2005).

The beneficial effects of EF have shown to be further strengthened when EF is directed to a location that is spatially farther from the body (McNevin et al., 2003; Wulf et al., 2000). For example, McNevin et al. (2003) manipulated the distance of EF cues by attaching markers on a rectangle-shaped unstable platform during a balance task. A pair of markers was attached near the participants' feet (EF-near), and another pair was attached near the platform's edges (EF-far). In both conditions, participants received the same attentional focus cue (i.e., "focus on keeping the markers parallel to the floor") and the visual fixation instructions (i.e., "look at the cross-hair on the wall"). The results showed that the EF-near condition was still better than the IF condition, and the EF-far condition outperformed both EF-near and IF conditions. McNevin et al. (2003) proposed that an EF-far promotes even greater automaticity than an EF-near because individuals can clearly distinguish EF from IF. Subsequent research supported this distance effect in various motor skills (Banks et al., 2020; Bell & Hardy, 2009; Coker, 2016; Duke et al., 2011; Kearney, 2015; King & Power, 2021; Porter et al., 2012, 2013; Singh & Wulf, 2020).

According to the *constrained action hypothesis* (McNevin et al., 2003; Wulf, McNevin, et al., 2001; Wulf, Shea, et al., 2001), conscious control of body movements disrupts the natural motor processes, whereas an EF reduces conscious motor control and frees up attentional resources, promoting the motor systems' self-organization tendencies. Consequently, EF enhances performance, and the effect of automatization is strengthened when an EF is directed spatially farther from the source of the disruption (i.e., IF). The proposition has been supported empirically, showing that EF resulted in a more efficient force generation or neuromuscular activity than IF (Marchant, 2011, for review). In addition, studies found that an EF led to superior dual-task performance (Kal et al., 2013; Wulf, McNevin, & Shea, 2001). Given the limited central resource capacity assumption, simultaneously performing two tasks would consume more attentional resources than a single task (Abernethy, 1988; Baddeley, 2000; Baddeley & Hitch, 1974). When limited resources compete between two tasks, an intervention that facilitates information processing or requires fewer resources is beneficial. Leveraging this research paradigm, Kal et al. (2013) and Wulf, McNevin, and Shea (2001) showed that EF led to better dual-tasking performance than IF, implying that EF may promote a more efficient cognitive processing relative to an IF.

Although many studies showed the beneficial effects of an EF, bimanual tasks have rarely been studied. Bimanual tasks are most ubiquitous in activities of daily life (Kilbreath & Heard, 2005), including, but not limited to, dishwashing, buttoning a shirt, transporting coffee mugs with a tray, and eating with a fork and knife. Thus, there is a need to investigate the effect of EF and IF on this type of skill. Previous research has revealed that attention changes bimanual coordination patterns, for example, whether attention is directed to the task or other events (Monno et al., 2002, for a review) or attention is directed to the preferred or nonpreferred limb (Pellegrini et al., 2004; Wuyts et al., 1996). Currently, little is known regarding the effect of EF and IF on bimanual tasks. Among a few studies, a bimanual task (wrist flexion/extension task) that adopted EF/IF cues did not show statistical differences (De Boer et al., 2013; Hodges & Franks, 2000). One possible explanation is that the EF/IF cue may not be effective in bimanual tasks as participants need to pay attention to both limbs and thus cannot maintain their focus on one cue. However, other potential confounding variables existed. First, the content of instruction in both studies may have led to the equivocal results. The IF cue used in the study by De Boer et al. (2013) was to focus on alternating the wrist movements in accordance with the pacing signal, which can be a mixture of EF (externally introduced tones) and IF (wrist movements) cues. The EF cue used by Hodges and Franks (2000) was not directed to a specific movement component. Instead, the instructions were to be careful with the feedback from the demonstration that they received. Thus, participants could have directed their attention internally or externally (e.g., thinking internally or externally about how to plan motor execution based on the demonstration). In addition, both studies removed natural visual feedback (i.e., visions of arms). Although this visual manipulation is a typical procedure to eliminate the influence of vision on performance, altering naturally available feedback may have distorted the EF/IF effects. In the present study, participants had visual feedback naturally available as real-world situations to maximize external validity. In addition, we provided specific attentional focus cues to examine whether EF or IF would be effective in bimanual tasks after modifying these potentially confounding factors.

Our secondary purpose was to test the effect of visual information. One assumption of the EF/IF effect is that the factor driving the performance difference between EF and IF is primarily cognitive (i.e., what learners think about) rather than visual (i.e., what learners look at, such as target vs. arm). However, the effect of vision on EF/IF is still equivocal. On the one hand, EF resulted in superior performance to IF during a balance task even when participants' visual focus was fixated on one location (Wulf, McNevin, & Shea, 2001). In addition, in a tracking task, when participants traced a moving ball on a display with a computer mouse, the accuracy of tracing the ball was better under the EF condition than the IF condition, even when the moving ball was occluded from the display (Schlesinger et al., 2013). On the other hand, as found in De Boer et al. (2013) and Hodges and Franks (2000), EF and IF were not statistically different when natural visual feedback was eliminated. These findings were further supported in other non-bimanual tasks. Some studies did not show a statistical difference between an EF and IF when natural visual feedback was unavailable (Chen et al., 2021; Perkins-Ceccato et al., 2003).

To examine the effect of vision on attentional focus, we adopted different types of dual tasks. In the previous literature that adopted a dual-task procedure, the investigators chose a secondary task that did not overlap with the predominant sensory modality required for the primary task (e.g., a balance task with an auditory secondary task in Wulf, McNevin et al., 2001). Wulf, McNevin et al., (2001) chose a secondary task because the benefits of EF during dual tasking could be due to the distraction of the visual information by the secondary task (if the two tasks require the same sensory modalities). In the present study, we purposefully crossed together the relevant sensory inputs (i.e., vision). In one dual-task condition, the primary task was a bimanual tracking task that predominantly required visual information, with the secondary task being a reaction time (RT) task in response to auditory stimuli, replicating Wulf et al. (2001). In another dual task, participants completed the dual task with a secondary task requiring responses to visual stimuli, overlapping the primary sensory modalities for both tasks. If the EF/IF is predominantly cognitive with little effect by vision, the nature of the secondary task should not affect the relationship between EF and IF. Conversely, if the benefit of EF is partially because of visual information, there would be an interaction effect between the auditory and visual dual-task conditions. Thus, we adopted a dual-task procedure to assess the effect of visual information (i.e., visual distraction) rather than a test of attentional capacity or process efficiency.

Therefore, the purposes of the present exploratory study were twofold: (1) to investigate the effect of attentional focus when performing a bimanual task and (2) to investigate the effect of visual distraction with dual tasks. Participants in the IF, EF-near, or EF-far group practiced a bimanual task (Purpose 1). Participants revisited the laboratory in 48 hr and completed the same task with a dual-task procedure: one condition in response to auditory stimuli and the other in response to visual stimuli (Purpose 2). We hypothesized that the EF-far group would outperform the EF-near group and the EF-near group would outperform the IF group in the bimanual task. We also hypothesized that the performance difference between the EFs and IF groups would be attenuated (i.e., interaction effect) during the visual dual task relative to performance during the auditory dual task.

Methods

Participants

Fifty-one university students participated in the study ($M_{age} = 22.40 \pm 1.27$). Originally, it was planned to collect more than 42 participants, which was the sample size collected in a previous study with a similar study design (i.e., the same task and three between-subject groups; Zarezade et al., 2018). Given the small effect size of the attentional focus effect (McKay et al., 2023), 42 participants may not have been sufficient. However, we did not have enough time to collect data. Thus, we aimed to collect as many participants as possible within the approved timeframe (4 weeks) for data collection. Therefore, it is important to note that we did not have a planned sample size estimation analysis.

Participants were recruited through flyers. To be included in the study, participants must have corrected vision and be naïve to the task used in the study. Participants were excluded if they had neurological impairments or visual impairments. All participants were males and right-handed with no impairments. The study was approved by the Review Board of the Shahid Bahonar University Ethical Committee, and the participants' informed consent was obtained.

Apparatus and Procedure

Participants completed the demographics (age, gender, height, and weight), an inclusion criteria questionnaire ("Do you wear glasses or has the doctor prescribed glasses?" and "Do you have any neurological conditions or impairments that affect vision, cognition, or movements?"), and the hand dominance questionnaire ("Which hand is your dominant hand when writing?"). All participants were males and right-handed. Then, participants were randomly assigned to one of the

EF-near ($n = 17$; $M_{age} = 22.65 \pm 1.46$ years; $M_{height} = 174.51 \pm 4.09$ cm; $M_{mass} = 73.28 \pm 3.94$ kg), EF-far ($n = 17$; $M_{age} = 22.29 \pm 1.60$ years; $M_{height} = 176.36 \pm 3.48$ cm; $M_{mass} = 75.68 \pm 5.18$ kg), and IF ($n = 17$; $M_{age} = 22.29 \pm 1.22$ years; $M_{height} = 170.20 \pm 3.96$ cm; $M_{mass} = 70.53 \pm 4.29$ kg) groups.

The primary task was a bimanual tracking task (Vienna Test System, version 28; Figure 1). Participants held two joysticks and navigated a cursor through a predetermined course on a computer screen. At the beginning of the experiment, participants sat in a chair in front of a table. A controller board with two joysticks was located on the table at a comfortable distance from the participants (Figure 1). The task required participants to control a red circle on a computer screen with two joysticks, one with each hand, from the start to the goal position through a gray-colored course with a white background. The left joystick moved horizontally, and the right joystick moved vertically, allowing diagonal movements when both sticks moved simultaneously. The course (Figure 1) included sections that only require horizontal or vertical movements and sections that require diagonal movements. The red circle can deviate outside the course, and auditory feedback (beeps) was provided whenever the circle touched the edges of the course or deviated outside the course. To begin a trial, participants moved a circle to the start position with the two joysticks. When the circle reached the start position, the course and the end position appeared, indicating the start of a trial. When the circle reached the end position, the course disappeared again, and the start position appeared to begin the subsequent trial.

On Day 1, all participants were informed, “The purpose of the study is to improve your coordination skills, and the goal of the task is to move the red circle through the course as quickly as possible while emphasizing accuracy.” Two familiarization trials were provided prior to the baseline measures. After the familiarization trials, participants completed four baseline trials with no attentional focus instructions. On a separate day, participants in each group received different attentional focus instructions. Participants in the IF group were told to “focus on moving the right hand vertically and focus on moving the left hand horizontally.”

Figure 1 — Task and experimental setting. *Note.* (Left) The bimanual task used in the present study (the course displayed on the computer screen is the task used in the present study). (Right) Foot pedal to respond to the secondary task (A), computer display for the primary task (B), and visual stimuli presented for the visual secondary task (C).

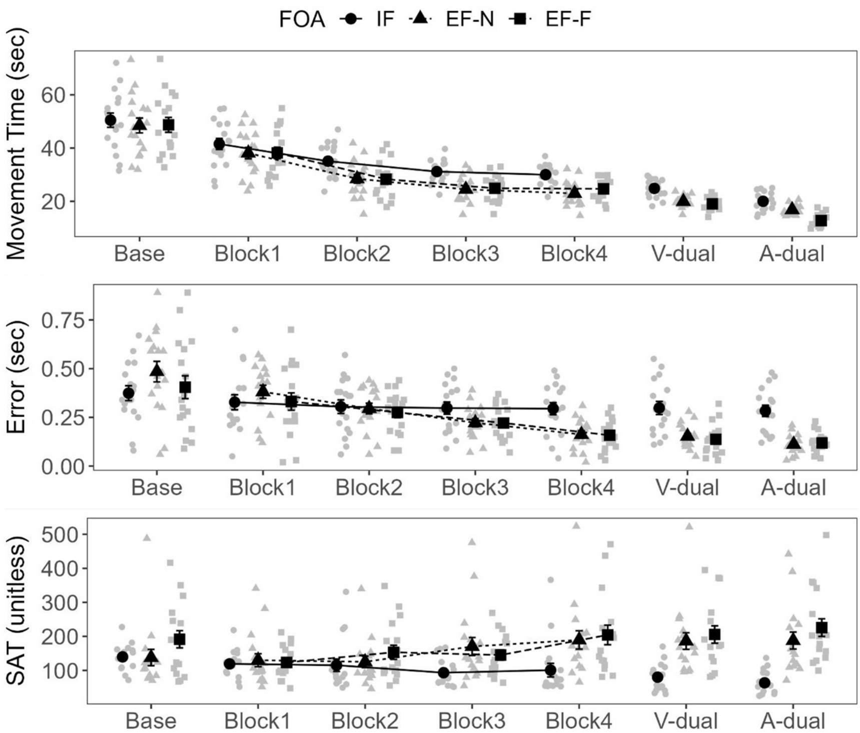

Figure 2 — Movement time, Error, and SAT scores. *Note.* Gray dots are individual data points, and bars are *SE* at each time point within the group. For movement time and Error, a lower value indicates a better performance. For SAT, a higher value indicates a better performance. SAT = speed–accuracy trade-off; Base = baseline; V-dual = visual dual task; A-dual = auditory dual task; FOA = focus of attention group; IF = internal focus; EF-N = external focus-near; EF-F = external focus-far.

Participants in the EF-near group were informed to "focus on moving the right joystick vertically and focus on moving the left joystick horizontally." For the EF-far group, three points were marked on the course, and the participants in the EF-far group were told to "focus on reaching the next point as fast as possible." All participants practiced the task for four blocks of four trials with assigned attentional focus instructions. They were reminded of the attentional focus instructions before the beginning of each block.

After 48 hr from Day 1, participants revisited the laboratory. First, participants completed one 60-s trial of a probe RT task in response to visual or auditory stimuli (i.e., the secondary task baseline). This secondary task device was customized using a computer (Samsung, model NP300V5A) and a foot pedal. A foot pedal was connected to the computer (Figure 1). The pedal was placed under the participant's right foot, and the computer screen was placed next to the computer display for the primary task. During the visual task, participants stepped on the pedal as soon as the display's color changed from white to red. The computer screen color switched back to white when participants stepped on the pedal. In the auditory task, participants stepped on the pedal as soon as they heard a beep, which was a different sound from the beep when a red circle deviated from the main course. The interval between the stimuli varied randomly between 5 and 10 s (Schoor et al., 2012), which provides, on average, eight stimuli for each trial. After the single RT task, participants completed the same bimanual coordination task for four trials with a secondary visual task (visual dual task) and four trials with a secondary auditory task (auditory dual task).

The rationale of the study design came from a pilot study ($N = 6$). Using movement time (MT), we identified that the task required four blocks to approximate plateau performance and four trials in each block would minimize mental and physical fatigue. We also found that an additional block caused mental fatigue based on our retrospective interview. Consequently, a dual-task procedure was planned in a separate session.

Analysis

All analyses were conducted with R. The dependent variables were MT (a total time in seconds when the cursor was inside the course), Error (a total time in seconds when the cursor was outside the course), and the speed–accuracy tradeoff score (SAT; unitless). A lower value of MT indicates a better performance, and a lower value of Error indicates better accuracy (less time spent outside the course). For SAT, MT was flipped (i.e., $[\max(MT_i) - MT_i] + \min(MT_i)$, where MT_i indicates the ith subject of MT) so that a *higher* MT indicates a better score. Then, the ratio of this flipped MT to Error was obtained. For example, an individual can perform faster by sacrificing error (e.g., 6 MT/12 Error = 0.5) or perform more accurately by sacrificing the speed (e.g., 3 MT/6 Error = 0.5). For the SAT, a higher SAT indicates a better performance (either improved MT with no change in Error, reduced Error with no change in MT, or improvements in both MT and Error).

The average of each block (four trials) of the dependent variables was calculated. The assumptions of normality were inspected with box plots, histograms with density plots, and q-q plots. We additionally used the median absolute distance method with a threshold of 4 to quantify extreme scores. No outliers were detected for MT or Error using any of the methods. However, we identified multiple outliers for SAT, which was found to be a random pattern (i.e., different participants had extreme scores at different blocks at different times). The highest median absolute distance threshold found among all phases was 540.0785 (Block 4). We decided to remove the scores above 540.0785. Consequently, three outliers in the baseline, eight outliers in the acquisition phase, and three outliers in the dual-task phase were identified and removed. For the primary analyses, it was originally planned to test the dependent variables with a Group × Block analysis of variance (ANOVA). To account for missing data (i.e., removed outliers), we adopted a mixed-effect model. The between-subject fixed factor was Group. The within-subject fixed factor was Time. The individual intercept was considered a random factor. The F and p values of the fixed effects were obtained by the lmerTest package (Kuznetsova et al., 2017), with the degrees of freedom adjusted by the Kenward–Roger method. Post hoc tests were performed with the emmeans packages (Lenth et al., 2018). The baseline performance and demographic differences were measured with a one-way ANOVA between groups. ANOVAs were analyzed using the rstatix package (Kassambara, 2023). Partial eta squared (η_p^2) was used for the effect size of the ANOVA results. An alpha was set at .05 for all analyses. If significance was observed, a simple effect analysis was performed, followed by pairwise comparisons with Bonferroni corrections at an $\alpha = .05$.

Results

Demographics

Using one-way ANOVA, age, $F(2, 48) = 0.429$, $p = .653$, $\eta_p^2 = .018$, was not significantly different between groups. However, height and weight, $F(2, 48) = 5.564$, $p = .007$, $\eta_p^2 = .188$, were different, $F(2, 48) = 11.410$, $p < .001$, $\eta_p^2 = .322$, suggesting that participants in the EF-far group were significantly taller and heavier than the participants in the IF group.

Baseline Performance

Table 1 summarizes the mean, *SD*, and 95% confidence interval (CI) of performance between groups across time. At the baseline, there was no group difference (one-way ANOVA) for any variables: MT, $F(2, 48) = 1.157$, $p = .855$, $\eta_p^2 = .007$, Error, $F(2, 48) = 1.280$, $p = .287$, $\eta_p^2 = .051$, and SAT, $F(2, 45) = 2.004$, $p = .147$, $\eta_p^2 = .082$.

The Attentional Focus Effect in the Bimanual Task

For MT, significant results were found in the group (Figure 2), $F(2, 48) = 5.883$, $p = .005$, and block effects, $F(3, 144) = 161.268$, $p < .001$, with no interaction effect, $F(3, 144) = 1.398$, $p = .219$. The post hoc test of the group factor showed that the IF group ($M = 34.4$ s, $SE = 1.36$, 95% CI [31.7, 37.2]) (i.e., the means are estimated marginal mean with *SE*) performed worse than both the EF-near group, $t(48) = 3.095$, $p = .001$, $M = 28.5$ s, $SE = 1.36$, 95% CI [25.8, 31.2], and EF-far group, $t(48) = 2.829$, $p = .020$, $M = 28.5$ s, $SE = 1.36$, 95% CI [26.3, 31.8], with no difference between the EF groups, $t(48) = -.266$, $p = 1.000$. The post hoc test for the block factor showed that all time points were significantly different (i.e., improving MT) from each block, Blocks 1–2: $t(144) = 12.759$, $p < .001$; Blocks 1–3: $t(144) = 18.301$, $p < .001$; Blocks 1–4: $t(144) = 19.717$, $p < .001$; Blocks 2–3: $t(144) = 5.542$, $p < .001$; Blocks 2–4: $t(144) = 6.958$, $p < .001$, except between Blocks 3 and 4, $t(144) = 1.416$, $p = .928$.

For Error, significance was observed in block, $F(3, 144) = 21.712$, $p < .001$, which was superseded by the interaction between group and block, $F(6, 144) = 3.494$, $p = .003$. A main effect of the group was not observed, $F(2, 48) = 1.811$, $p = .174$. For post hoc tests of the interaction, simple effect analyses of each group showed that the IF group did not significantly change Error across all blocks, $F(3, 48) = 0.3822$, $p = .766$. However, both EF-near, $F(3, 48) = 30.005$, $p < .001$, and EF-far, $F(3, 48) = 8.440$, $p < .001$, groups significantly improved Error. Pairwise comparisons for the EF-near group showed that the initial three

Table 1 **Mean (*SD*) and 95%Confidence Interval [Lower Limit, Upper Limit] of the Dependent Variables**

Group	Baseline	Block 1	Block 2	Block 3	Block 4	V-dual task	A-dual task
MT							
IF	50.47 (11.06); [44.79, 56.16]	41.54 (8.60); [37.12, 45.96]	35.07 (6.39); [31.79, 38.36]	31.17 (4.20); [29.01, 33.33]	30.01 (3.70); [28.11, 31.92]	24.86 (3.49); [23.07, 26.66]	20.01 (3.55); [18.19, 21.84]
EF-N	48.48 (11.43); [42.60, 54.36]	38.11 (8.61); [33.68, 42.54]	28.47 (6.80); [24.98, 31.97]	24.49 (4.84); [22.00, 26.98]	22.98 (4.69); [20.57, 25.39]	19.92 (2.15); [18.81, 21.02]	16.84 (1.83); [15.90, 17.78]
EF-F	48.72 (11.48); [43.28, 54.97]	38.19 (8.88); [33.95, 43.09]	28.31 (6.98); [25.00, 32.17]	24.90 (5.14); [22.46, 27.79]	24.69 (3.90); [22.84, 26.86]	19.05 (2.33); [17.98, 20.39]	12.75 (2.51); [11.46, 14.04]
Error							
IF	0.37 (0.16); [0.29, 0.45]	0.33 (0.16); [0.25, 0.41]	0.30 (0.14); [0.23, 0.38]	0.30 (0.13); [0.23, 0.36]	0.30 (0.13); [0.23, 0.36]	0.30 (0.14); [0.22, 0.37]	0.28 (0.11); [0.22, 0.34]
EF-N	0.48 (0.14); [0.37, 0.60]	0.38 (0.12); [0.31, 0.45]	0.30 (0.22); [0.24, 0.35]	0.22 (0.14); [0.18, 0.27]	0.16 (0.11); [0.12, 0.20]	0.15 (0.09); [0.12, 0.18]	0.11 (0.08); [0.09, 0.14]
EF-F	0.40 (0.24); [0.28, 0.53]	0.33 (0.18); [0.24, 0.43]	0.28 (0.11); [0.22, 0.33]	0.22 (0.09); [0.18, 0.27]	0.16 (0.08); [0.12, 0.20]	0.14 (0.08); [0.10, 0.18]	0.12 (0.05); [0.09, 0.15]
SAT							
IF	139.67 (39.51); [119.35, 159.99]	119.14 (40.74); [98.20, 140.09]	115.09 (74.91); [76.57, 153.61]	93.17 (39.52); [72.85, 113.49]	100.65 (81.87); [58.56, 142.75]	80.07 (42.99); [57.97, 102.17]	63.45 (33.62); [46.17, 80.74]
EF-N	137.76 (99.26); [86.72, 188.79]	129.88 (78.23); [89.65, 170.10]	125.11 (69.12); [89.57, 160.10]	170.19 (108.86); [114.22, 226.16]	189.50 (110.67); [132.60, 246.40]	186.23 (100.44); [134.59, 237.88]	187.70 (102.68); [134.91, 240.50]
EF-F	191.42 (104.13); [137.88, 244.96]	123.38 (50.61); [97.36, 149.40]	153.14 (85.34); [109.27, 197.02]	145.10 (62.19); [113.12, 177.08]	204.19 (118.67); [143.18, 265.20]	205.49 (104.89); [151.56, 259.42]	225.69 (106.61); [170.87, 280.50]

Note. The unit of measurement is in seconds. SAT is unitless with a higher value indicating a better performance. MT = movement time; SAT = speed–accuracy trade-off; IF = internal focus; EF-N = external focus-near; EF-F = external focus-far; V-dual task = visual dual task; A-dual task = auditory dual task.

blocks (Block 1: $M = 0.381$ s, $SE = 0.026$, 95% CI [0.329, 0.433]; Block 2: $M = 0.295$, $SE = 0.026$, 95% CI [0.243, 0.348]) were significantly different from each other, Blocks 1–2: $t(48) = 3.522$, $p = .006$; Blocks 1–3: $t(48) = 6.512$, $p < .001$; Blocks 1–4: $t(48) = 8.973$, $p < .001$; Blocks 2–3: $t(48) = 2.991$, $p = .026$; Blocks 2–4: $t(48) = 5.451$, $p < .001$, except the last two blocks, Block 3: $M = 0.222$ s, $SE = 0.026$, 95% CI [0.170, 0.275]; Block 2: $M = 0.162$ s, $SE = 0.026$, 95% CI [0.110, 0.215], $t(48) = 2.460$, $p = .105$. For the EF-far group, blocks between 1 ($M = 0.331$ s, $SE = 0.030$, 95% CI [0.272, 0.391]) and 3 ($M = 0.221$ s, $SE = 0.030$, 95% CI [0.162, 0.281]), $t(48) = 3.053$, $p = .022$, 1 and 4 ($M = 0.158$ s, $SE = 0.030$, 95% CI [0.099, 0.218]), $t(48) = 4.801$, $p = .001$, and 2 and 4, $t(48) = 3.249$, $p = .013$, were significantly different. However, blocks between 1 and 2, $t(48) = 1.551$, $p = .765$, 2 and 3, $t(48) = 1.502$, $p = .838$, and 3 and 4, $t(48) = 1.745$, $p = .522$, were not significantly different.

For the post hoc analyses between groups at each time point, in Blocks 1, 2 and 3, there was no group difference in the first three blocks: Block 1 between IF and EF-near, $t(123) = -1.264$, $p = .626$, Block 1 between IF and EF-far, $t(123) = -.083$, $p = 1.000$, Block 1 between EF-near and Ef-far, $t(123) = 1.181$, $p = .720$; Block 2 between IF and EF-near, $t(123) = .222$, $p = 1.000$, Block 2 between IF and EF-far, $t(123) = .695$, $p = 1.000$, Block 2 between EF-near and EF-far, $t(123) = .472$, $p = 1.000$; and Block 3 between IF and EF-near, $t(123) = 1.778$, $p = .234$, Block 3 between IF and EF-far, $t(123) = 1.806$, $p = .220$, Block 3 between EF-near and EF-far, $t(123) = .028$, $p = 1.000$. However, in the last block, the IF and EF-near, $t(123) = 3.126$, $p = .007$, and IF and EF-far groups, $t(123) = 3.223$, $p = .005$, were statistically different, with no difference between the EF-near and EF-far groups, $t(123) = .097$, $p = 1.000$.

For SAT, a significant difference was observed in the group, $F(2, 47.896) = 4.227$, $p = .020$, block, $F(3, 137.376) = 3.886$, $p = .011$, and interaction, $F(6, 137.356) = 2.417$, $p = .030$. The post hoc tests of simple effect analysis for each group showed that, for the IF group, SAT did not improve across all blocks, $F(3, 47.308) = 0.695$, $p = .560$. However, both EF-near, $F(3, 45.382) = 3.588$, $p = .021$, and EF-far groups, $F(3, 44.626) = 3.810$, $p = .016$, significantly improved SAT. Pairwise comparisons for the EF-near group showed that Blocks 1 ($M = 130$, $SE = 23.3$, 95% CI [82.6, 177]) and 4 ($M = 198$, $SE = 24.3$, 95% CI [149.3, 248]) were statistically different, $t(45.6) = -2.832$, $p = .041$. Other blocks were not statistically different: Blocks 1–2, $t(45.4) = -.168$, $p = 1.000$, Blocks 1–3, $t(45) = -1.738$, $p = .535$, Blocks 2–3, $t(45.4) = -1.534$, $p = .792$, Blocks 2–4, $t(45.2) = -2.644$, $p = .067$, and Blocks 3–4, $t(45.6) = -1.166$, $p = 1.000$. Similarly, the EF-far group also significantly improved from Block 1 ($M = 131$, $SE = 21.5$, 95% CI [87.5, 174]) to Block 4 ($M = 207$, $SE = 21.0$, 95% CI [164.8, 249]), $t(45) = -3.155$, $p = .017$. However, other blocks were not statistically different: Blocks 1–2, $t(44.6) = -.941$, $p = 1.000$, Blocks 1–3, $t(45) = -.696$, $p = 1.000$, Blocks 2–3, $t(44.3) = .237$, $p = 1.000$, Blocks 2–4, $t(44.3) = -2.322$, $p = .150$, and Blocks 3–4, $t(44.6) = -2.510$, $p = .095$.

For the post hoc analyses between groups at each time point, in Blocks 1 and 2, there was no group difference: Block 1 between IF and EF-near, $t(134) = -.411$, $p = 1.000$, Block 1 between IF and EF-far, $t(140) = -.431$, $p = 1.000$, Block 1 between EF-near and EF-far, $t(137) = -.031$, $p = 1.000$; Block 2 between IF and EF-near, $t(134) = -.604$, $p = 1.000$, Block 2 between

IF and EF-far, $t(131) = -1.358$, $p = .532$, and Block 2 between EF-near and EF-far, $t(134) = -.737$, $p = 1.000$. However, in Block 3, the IF group ($M = 93.2$, $SE = 19.8$, 95% CI [54, 132]) was worse than the EF-near group ($M = 170.2$, $SE = 19.8$, 95% CI [131, 209]), $t(131) = -2.749$, $p = .021$, with no difference between the IF and EF-far groups ($M = 147.6$, $SE = 20.3$, 95% CI [107.5, 188]), $t(134) = -1.921$, $p = .171$, and EF-near and EF-far groups, $t(124) = .796$, $p = 1.000$. In the last block, both EF-near, $M = 196.7$, $SE = 20.8$, 95% CI [155.6, 238], $t(137) = -3.343$, $p = .003$, and EF-far, $M = 207$, $SE = 20.3$, 95% CI [166.9, 247], $t(134) = -3.751$, $p < .001$, groups were better than the IF group, $M = 100.7$, $SE = 19.8$, 95% CI [61.5, 140], with no difference between the EF-near and EF-far groups, $t(139) = -.353$, $p = 1.000$.

The Attentional Focus Effect and Visual Information

For MT, significant main effects were found in all factors of the group, $F(2, 48) = 32.253$, $p < .001$, condition, $F(1, 48) = 171.181$, $p < .001$, and interaction terms, $F(2, 48) = 6.636$, $p = .003$, indicating that MT was faster in the auditory dual-task than the visual dual-task conditions. The post hoc tests revealed that, during the visual dual task, the IF group ($M = 24.9$ s, $SE = 0.661$, 95% CI [23.5, 26.2]) was worse than both the EF-near ($M = 19.9$ s, $SE = 0.661$, 95% CI [18.6, 21.2]) and EF-far ($M = 19.0$, $SE = 0.661$, 95% CI [17.7, 20.4]) groups, IF–EF-near: $t(73.8) = 5.294$, $p < .001$; IF–EF-far: $t(73.8) = 6.221$, $p < .001$, with no difference between the EF-near and EF-far groups, $t(73.8) = .928$, $p = 1.000$. During the auditory dual-task condition, all pairs of groups were significantly different from each other. The IF group, $M = 20.0$ s, $SE = 0.661$, 95% CI [18.7, 21.3], was worse than the EF-near group, $M = 16.8$ s, $SE = 0.661$, 95% CI [15.5, 18.2], $t(73.8) = 3.399$, $p = .003$, and the EF-far group, $M = 12.8$ s, $SE = 0.661$, 95% CI [11.4, 14.1], $t(73.8) = 7.780$, $p < .001$, and the EF-near group was worse than the EF-far group, $t(73.8) = 4.381$, $p = .001$.

For Error, significance was found in the main effects of condition, $F(1, 48) = 5.501$, $p = .023$, and group, $F(2, 48) = 22.016$, $p < .0001$, but not in interaction, $F(2, 48) = 0.600$, $p = .553$. Error was lower (i.e., better) during the auditory dual task ($M = 0.171$ s, $SE = 0.013$, 95% CI [0.146, 0.196]) than during the visual dual task ($M = 0.196$ s, $SE = 0.013$, 95% CI [0.171, 0.221]). The post hoc test for the group showed that the IF group, $M = 0.291$ s, $SE = 0.020$, 95% CI [0.251, 0.331], had greater errors than the EF-near group, $M = 0.132$ s, $SE = 0.020$, 95% CI [0.093, 0.172], $t(48) = 5.672$, $p < .001$, and EF-far group, $M = 0.128$ s, $SE = 0.020$, 95% CI [0.089, 0.168], $t(48) = 5.819$, $p < .001$, with no difference between the EF groups, $t(48) = 0.147$, $p = 1.000$.

For SAT, a significant difference was found in the group, $F(2, 47.211) = 25.507$, $p < .001$. The condition, $F(1, 47.231) = 0.009$, $p = .924$, and interaction terms, $F(2, 47.211) = 0.368$, $p = .694$, were not statistically different. The post hoc test for the group showed that the IF group, $M = 71.8$, $SE = 14.9$, 95% CI [41.7, 102], had a worse SAT score than the EF-near group, $M = 187$, $SE = 15.2$, 95% CI [156.5, 217], $t(46.5) = -5.419$, $p < .001$, and EF-far group, $M = 215.6$, $SE = 15.4$, 95% CI [184.6, 247], $t(47.3) = -6.704$, $p < .001$, with no difference between the EF groups, $t(48) = -1.324$, $p = .576$.

The Confirmation Analyses of the Dual-Task Effects

To further understand the effect of dual tasks, RT of the secondary tasks during a simple RT task (i.e., a RT task in response to auditory or visual stimuli without the bimanual task) and during the dual tasks were analyzed. A three-way ANOVA between Group (IF/EF-near/EF-far), Modality (Visual/Auditory), and Condition (Simple/Dual task), with repeated-measures factors being Modality and Condition, was conducted. The results showed no attentional focus effect, $F(2, 48) = 0.615$, $p = .545$, $\eta_p^2 = .025$, or any interactions related to attentional focus, Group × Condition: $F(2, 48) = 0.108$, $p = .898$, $\eta_p^2 = .004$; Group × Modality: $F(2, 48) = 2.793$, $p = .071$, $\eta_p^2 = .104$; Group × Condition × Modality: $F(2, 48) = 1.521$, $p = .229$, $\eta_p^2 = .060$. Significant effects were found in Condition, $F(1, 48) = 455.788$, $p < .001$, $\eta_p^2 = .905$, Modality, $F(1, 48) = 348.973$, $p < .001$, $\eta_p^2 = .879$, and the interaction between Condition and Modality, $F(1, 48) = 537.681$, $p < .001$, $\eta_p^2 = .918$. Post hoc tests showed that, during the simple RT, RT in response to the auditory stimuli were slightly but significantly faster than in response to the visual stimuli, $t(50) = -2.0574$, $p = .045$. However, it is noted that the difference between the two modality RTs was less than 0.02 s (visual RT: $M = 0.497 \pm 0.080$ s; auditory RT: $M = 0.480 \pm 0.076$). For RT during the dual-task condition, the visual RT ($M = 0.642 \pm 0.054$ s) was faster than the auditory RT ($M = 0.842 \pm 0.051$ s), $t(50) = 36.499$, $p < .001$. For the difference between simple RT and dual RT within each modality, simple RT was significantly faster than the dual RT for both auditory, $t(50) = -30.771$, $p < .001$, and visual, $t(50) = -10.908$, $p < .001$, suggesting that the source of interaction was modality.

Discussion

The present study was a preliminary investigation into the effect of attentional focus in a bimanual task and the effect of distraction via an auditory or visual secondary task. It was hypothesized that the EF-far group would outperform the EF-near group, and the EF-near group would perform better than the IF group in the bimanual task. Our first hypothesis regarding the attentional focus effect was partially supported. Unlike the previous reports (De Boer et al., 2013; Hodges & Franks, 2000), we observed the attentional focus effect in a bimanual task. These previous studies used cues that can be considered either EF or IF and partially occluded visual information the participants received. After modifying these two factors, we found that EF was superior to IF in a bimanual task. Thus, it is possible that the EF benefits were not evident in the previous bimanual tasks because of these factors. We also found two interesting results: (a) the IF group did not improve in error throughout the experiment, whereas both EF groups improved in error; and (b) the attentional focus difference was not observed in Blocks 1, 2, and 3 but emerged in Block 4. Regarding dual task, we hypothesized that the performance difference between the EFs and IF groups would attenuate more (i.e., interaction effect) during the visual dual task than during the auditory dual task. During the visual dual-task condition, the IF group was inferior to both EF groups. However, in the auditory dual-task condition, the EF-far group outperformed (in MT) the EF-near and IF groups, and the EF-near group outperformed the IF group.

The Distant Effect

Our hypothesis was *partially* supported because we found the attentional focus effect specific to EF and IF but did not find the distance effect (EF-far vs. EF-near). Previously, McNevin et al. (2003; i.e., the constrained action hypothesis) proposed that an EF-far cue is more beneficial because it is spatially distinguishable from body-oriented cues (IF) than an EF-near cue. To this end, Schlesinger et al. (2013) and our studies allocated the participants' attention spatially farther from IF for the EF-far condition (focus on the cursor on the computer screen) and spatially closer from IF for the EF-near condition (focus on the computer mouse or joysticks for EF-near vs. focus on the hand using the mouse or joysticks for IF). Yet, neither Schlesinger et al. (2013) nor our study found differences between EF-far and EF-near and showed the beneficial effect of EF-near over IF. Thus, there seem to be other explanations beyond the perception of distance between IF and EF cues.

A potential alternative explanation is that the detrimental effect of IF is greater than the beneficial effect of EFs. When examining the specific instruction used in the present study, the default (task goal) instruction for the SAT task ("to move the red circle through the course as quickly as possible while emphasizing accuracy") could be naturally an external focus-driven task. Thus, environmental cues such as the joysticks (EF-near) and cursor (EF-far) are more salient when performing a visuomotor skill, that is, participants may have implicitly focused on these cues regardless of the given attentional focus cues. Indeed, some recent studies showed that IF may be beneficial for a body-oriented task (e.g., dance) and EF may be beneficial for an environmentally oriented task (e.g., tennis, basketball) (Gottwald et al.,2020; Wähnert & Müller-Plath, 2021). In this regard, the EF-far group could be considered a "control" group (a group without specific attentional focus instruction). Because of the nature of the task, we acknowledge that the effect of IF was a mixture of IF (instruction) and EF (task goal). However, the provision of task goal instructions was critical for the SAT task to ensure accuracy was maximized during task execution. Future studies may need to consider the nature of the task.

There are other emerging hypotheses regarding the effect of the attentional focus effects. Most of them are variations of a similar concept. One is the relevance of the information. Herrebrøden (2023) proposed that the negative effect of IF may be because IF is less relevant than EF. Herrebrøden (2023) defined *task-relevant information* as "meaningful (nonrandom) stimuli that facilitate task success" (pp. 126) and proposed that successful motor execution requires attunement of the performer's attention to the task-relevant information. This concept of relevant information is similar to Gentile's (1972) concept of regulatory conditions: environmental characteristics that determine or mold the performer's movement patterns. Thus, EF is beneficial because it is inherently directing the performer's attention to the task-relevant information. Similarly, another line of work showed and proposed that EF is more congruous to the implicitly learned task goal, whereas IF causes conflict between the task goal and the provided attentional focus instructions (Zentgraf & Munzert, 2009). Consequently, (experimentally) forcing participants to pay attention to a less relevant cue (e.g., hand movements) could deviate the participants' attention *away* from the relevant cues (Yamada et al., 2024). Thus, it is possible that the benefits of the distance effect also depend on the similarity between the task goal and provided attentional focus cues. A third variant of the similar concept is that an IF cue would be an additional piece of information that can increase (potentially unnecessary) the load on the working memory (Masters & Maxwell, 2008; Poolton et al., 2006), which can be detrimental, especially under psychological pressure. In our study, the EF-near focus cue would be an additional piece of information or more specific information regarding the mechanics of the skill (i.e., the joystick movements). Likewise, thinking about the hand movements in the IF group was also an additional piece of information compared with the task goal instruction. Thus, the EF-far instruction may not add *new* information to the working memory.

We further propose a similar but different potential explanation, which is the *informativeness* of instructions. The difference between task-relevant information mentioned above and informativeness is operationally considered as the presence of individual differences. The definition of task-relevant information and the background theoretical framework presented by Herrebrøden (2023) imply that there are invariant (nonrandom) environmental characteristics that dictate task success. For example, Herrebrøden (2023) stated that the end goal is the most crucial information (and thereby, task-relevant information); motor planning is created "backward" from the end goal. Although the author's expression and theoretical background are different, we agree with this statement as this concept of inverse kinematics and dynamics (Atkeson, 1989) is the foundation of engineering, robotics, and many motor control theories. One difference that we propose is that the relevance of information can be subjectively different based on individual characteristics and experiences (i.e., operationally defined as informativeness). For example, in our study, the course was divided into three subsections, which required different patterns of coordination of the right- and left-hand joysticks. There were markers at the end of each subsection. Thus, these markers may be facilitative to switch the participants' foci to different strategies rather than having a single end goal to some individuals. This explanation could potentially provide some clues for why, in some previous work, attentional focus cues were ineffective. For example, Maurer and Munzert (2013) showed that participants performed the given task better with their familiar instruction regardless of EF or IF. Therefore, task-relevant information may be present; however, the relevance to *the recipient* of the instructional cue may also play a crucial role. It is noted that quantifying the concepts of relevance and informativeness proposed by these hypotheses would be challenging. It may involve the subjective opinions of the investigators to decide what cues are informative or truly relevant as nonrandom features of the environment. The relevance may even be different among learners (i.e., different cues may be relevant for different individuals, depending on the anatomical, cognitive, or other perspectives of individual differences). Regardless, future studies are warranted to investigate whether the mechanism of the distance effect really is because of spatial distance.

The Attentional Focus Effect Between EF and IF

Our hypothesis was supported when we focused on the relationship between EF and IF. Our results were consistent with previous literature regarding the benefits of

EF over IF (Chua et al., 2021; Wulf, 2013). However, we did not predict that the attentional focus effects would only emerge in the later block of the experiment. Previously, this "delayed effect" of attentional focus has been reported (Wulf et al., 1998; Wulf, McNevin, & Shea, 2001; Yamada et al., 2022), although some tasks clearly show an immediate benefit of EF (Nicklas et al., 2022, for a review). An important question is why this interaction is evident only in some skills but not others. As a potential explanation, we borrowed a hypothesis from the bimanual coordination paradigm. Doost et al. (2017) proposed that individuals first establish a *general control policy*, a configuration of general movement patterns (e.g., how to use the two joysticks to move a cursor up and down or side to side). Then, individuals establish a *specific control policy*, which is the task-specific motor configuration that depends on the specific context (e.g., on the shape and pattern of the course). This proposition is similar to Gentile's (1972) two-stage learning model, which is about "getting the idea of movements" in the initial learning stage and polishing the skill in the later stage, depending on the nature of the skill—diversify or fixate. In addition, Wulf et al. (2000) proposed a similar idea to the proposition of Doost et al. (2017) but more specific to EF and IF. Wulf et al. (2000) argued that individuals must first establish *fundamental movement* patterns: Novices would benefit from cues related to action components (e.g., forms and sequence of the body movements). After practice, they benefit from cues about the overall task goal (Wulf et al., 2000; Wulf & Su, 2007). Applying these propositions to our results, we could hypothesize that the delay of the attentional focus effects depends on the possession (or establishment) of the fundamental movement patterns. For example, a long-jump task has shown a 100% immediate effect (Makaruk et al., 2020, for a review). These participants (healthy young adults) could have already possessed the "general control policy." On the contrary, some tasks may be more novel to participants. In this case, participants may need to establish a general control policy at the beginning of the experiment, and during this stage, an attentional focus may not be effective. Thus, the task complexity and experience may affect the results of attentional focus. This hypothesis may allow some important studies to pursue in the future. For example, in a visuomotor tracking task across a course, one of the components of the skill acquisition may be visuospatial mapping (Murray et al., 2000), such as the direction and amplitude of a cursor movement about the joystick (or a computer mouse). Then, we could predict that the attentional focus effect would be delayed further if the task required more complex visuospatial mapping (e.g., a cursor moves in the opposite direction of the joystick).

Another novel finding from the present study was that the IF group did not improve errors. It is natural to see improvements in motor skills with practice. However, IF caused arrested development regarding the error duration improvement with continuous improvements in MT. Previously, in a SAT task, EF led to superior spatial accuracy over IF with no difference in the temporal errors (Raisbeck et al., 2020; Yamada, Kuznetsov, et al., 2021) or an IF resulted in an increased error with no performance difference in MT (Yamada et al., 2022). Therefore, it is possible that an IF interfered with error estimation/correction more substantially than execution speed. Future studies should investigate whether this phenomenon can be applied to other skills beyond a speed–accuracy task.

The Effect of Dual Task

When the performance (RT) of the secondary task was examined, our results showed little group difference regardless of the modality (i.e., auditory or visual stimuli). Also, RT during the dual-task conditions were slower than the simple RT tasks regardless of the modality. These results suggest that the dual-task manipulations were successful (sufficiently difficult) compared with the primary motor task alone, and there was no difference in task prioritization depending on groups.

However, when comparing RT between different modalities, we found that RT was noticeably slower during the dual-task condition in response to the auditory stimuli than the RT during the dual-task condition in response to the visual stimuli. It is noted that the primary task performance (i.e., SAT) did not differ between the auditory dual task and the visual dual task. Thus, this result suggests that the auditory secondary task was inherently more challenging than the visual secondary task. When we compare RT between auditory and visual secondary tasks, the auditory RT was faster than the visual RT. During the dual-task situation, however, the auditory RT was significantly *slower* than the visual RT. However, the difference between auditory RT and visual RT was approximately 0.02 s. Thus, the Condition × Modality interaction was driven by the presence of a relatively large modality effect during the dual-task condition and the absence of a similar effect during the simple-task condition.

Regarding the primary motor task, we conservatively conclude that our hypotheses regarding the dual-task effect were not supported. Performance during the visual dual task was more detrimental than during the auditory dual task. Although this appears to support our hypothesis, it is noted that the visual dual task always preceded the auditory dual task. As a result, we cannot confidently conclude that the nature of the secondary task affected the performance. However, the MT of the EF-far group was better than the EF-near group, and the EF-near outperformed the IF group during the auditory dual task. This distance effect was not evident during the visual dual task (both EFs were better than IF with no difference between EF-far and EF-near). As the cue of the EF-far was directed at the cursor, the visual distraction by the secondary task may have attenuated the beneficial effect of an EF-far. The same results would be expected if attentional focus specific to EF and IF is merely cognitive and independent from visual attention. When we explore the literature that investigated the effect of vision in clinical populations, findings are also inconsistent. Studies generally showed the benefits of an EF over IF in visually impaired individuals (Abdollahipour et al., 2020; McNamara et al., 2019), suggesting that EF may be independent of visual information. However, McNamara et al. (2017) showed that the EF benefits were evident in individuals with moderate impairments but not those with severe impairments. Congruous with our results, the finding by McNamara et al. (2017) suggests that visual information has a role in the effects of the distance effect. The result also aligns with the previous findings that the beneficial effect of EF relative to IF was not found when a part of naturally available visual information was occluded (Chen et al., 2021; De Boer et al., 2013; Hodges & Franks, 2000; Perkins-Ceccato et al., 2003). Thus, vision may affect the effect of attentional focus specific to EF and IF.

However, it is also noted that RT of the auditory dual task was slower than the visual dual task. It is possible that the distance effect during the auditory dual task was due to the task difficulty of the secondary task rather than solely due to the modality difference in the secondary task. Therefore, although our results may indicate that vision can, at least partially, moderate the attentional focus effect, further research is warranted.

Limitations and Future Directions

First, it is noted that we did not have a priori power analysis to estimate a sample size with sufficient statistical power. Instead, we collected as many participants as possible within the allowed timeframe. Thus, our results should be considered exploratory data, and we admit that the level of evidence in the present study may be limited. Another unique limitation of our results was a significant difference in participants' height (and thus weight) between groups. If the anthropometric measures affected the group factor, the performance difference should be evident in the baseline, and these groups may be consistently different. However, this was not the case for the present study. To confirm this result, we performed a simple linear regression (MT = height + error; Error = height + error), and both returned to be nonsignificant ($p = .219$ and $p = .479$ for MT and Error, respectively). However, the anthropometric measures (e.g., the hand or finger size relative to joysticks) may affect the results with a larger sample size. Alternatively, a larger sample size would have theoretically ameliorated the group difference given the appropriate recruitment procedure. Thus, a larger sample size study is necessary in the future to confirm the findings of the present study.

Regarding the design of the study, one of the limitations of the present study was visual attention. Although participants were instructed to pay attention to both tasks equally during the performance, we did not measure (did not have an apparatus, e.g., eye tracking) indications of visual attention toward the primary or secondary task. Also, if we define attentional focus (EFs and IFs) to be verbalizable conscious processes, a compliance check that asks what participants explicitly paid attention to during performance should have been collected as a part of the manipulation check. Future studies should investigate the visual factor and simultaneously adopt a manipulation check. Potentially, the relationship between a manipulation check and visual behavior may facilitate the understanding of the conscious thought process and visual attention, which can be a mixture of top-down and bottom-up attention. Our key limitation was the results during dual-task conditions. We conducted the dual-task procedure 48 hr after the practice phase. We originally planned to conduct the acquisition and dual-task condition phases in a single day. However, that would have exceeded the participation time and caused mental fatigue. We conducted this design to minimize the participation time and mental fatigue. However, this design my affect the interpretation because the outcome in the dual-task conditions may be affected by the learning effect. The results would have been clearer if the dual-task procedure was (a) inserted between the practice phase (to compare dual-task performance at different time points); (b) counterbalanced the visual and auditory dual task; (c) completed after a longer interval (e.g., 1 week after the practice phase); and (d) completed after a single motor task. Still, it is possible that the modality (auditory/visual) of the secondary task affected the attentional focus effects. Future studies should confirm this effect as this may supplement the interaction between cognitive attention and visual attention.

Another limitation (concern) is related to the definition. Although we believe the attentional focus effect difference across time is an important finding from this study, it is not clear what “fundamental movement pattern” (Wulf et al., 2000) or “general control policy” (Doost et al., 2017) is and how this early phase of learning differs from other phases of learning. With the data that we have available, we could not discuss this in detail. Future studies need to investigate a more elaborate definition of the substages of skill acquisition.

Also, the content instruction may have had an unequal “advantage.” Participants in the IF group were told to “focus on moving the right hand vertically and focus on moving the left hand horizontally.” Participants in the EF-near group were informed to “focus on moving the right joystick vertically and focus on moving the left joystick horizontally.” For participants in the EF-far group, three points were marked on the course, and the participants in the EF-far group were told to “focus on reaching the next point as fast as possible.” Only the EF-far group had an implication of the “speed,” whereas other groups did not have information about the speed of the movement. Future studies need more careful consideration regarding the equal quality of information between groups.

Finally, future studies should carefully choose attentional focus cues by considering different factors, including the relevance and informativeness of cues and the degree of additional information to the task goal. Also, the nature of the task or what performers implicitly learn without verbal instruction needs to be considered. In our study, we adopted a bimanual tracking task, and although one can argue that the task is complex, it is considerably simpler than sports skills. If the task is too simple, providing mechanistic instructions, such as focusing on the joystick or hand movements, may not be informative. By contrast, cues that prompt a learner to focus on the mechanics of the skill (e.g., IF or EF-near) may be more informative in a more complex skill that a learner must acquire fundamental movement patterns or movement mechanics than a skill used in laboratory research. Thus, investigation of the distance effect may require a combination of more systematic studies that assess the relevance or meaningfulness of information and applied studies that examine complex skills.

Conclusion

In the present study, we showed that both externally focused cues to a spatially proximal or distal location were effective in a bimanual task relative to a body-movement-focused cue. In addition, we found that the benefits of EFs over an IF were evident only after several blocks of trials, which was not present at the beginning of the practice. Interestingly, although the EF groups improved speed and accuracy, the IF group did not improve in error during a bimanual tracking task.

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Data Availability: The dataset used for this project is available at this link: https://osf.io/a7wnz/.

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