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Attentional Processes of High-Skilled Soccer Players With Congenital Hemiparesis: Differences Related to the Side of the Hemispheric Lesion

Bert Steenbergen and John van der Kamp

We investigated attentional processes that support the performance of high-skilled soccer players with hemiparetic cerebral palsy. Participants ($N = 10$) dribbled a slalom course as quickly and accurately as possible under two attentional-focus manipulation conditions. In the task-relevant focus condition, they attended to the foot that was in contact with the ball, whereas in the task-irrelevant focus condition, they monitored a series of words played on a tape. The time taken to complete the slalom course was registered. Performances of individuals with left and right hemiparesis were compared to explore differential effects of hemispheric lesion. The high-skilled players with congenital hemiparesis showed similar attentional-focus effects as those previously reported in the literature for high-skilled players without neurological disorders (Beilock et al., 2002; Ford et al., 2005). Task-relevant focus increased dribbling time, whereas a task-irrelevant focus did not result in a significant change in dribbling time. These findings generalized to each of the five participants with left hemiparesis (i.e., damage to the right hemisphere). By contrast, the effects of a task-relevant focus were less consistent for participants with right hemiparesis (i.e., left-hemisphere damage). This corroborates suggestions that the reinvestment of procedural knowledge is a left-lateralized function. The implications for the training of individuals with congenital brain damage are discussed.

Keywords: cerebral palsy, motor learning, working memory, sport, double task

Research on the consequences of early brain damage for motor performance has mainly assessed and underscored its debilitating effects. Ample studies in individuals with hemiparetic cerebral palsy (CP) showed deviations in motor performance (Utley & Sugden, 1998; Eliasson et al., 1991; Steenbergen & Gordon, 2006) even when upper-limb movements were performed with the less affected side (Steenbergen & Meulenbroek, 2006). Collectively, this work has advanced our insight into the deviations in motor control following congenital brain damage,

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as well as on the adaptability of the motor system. However, at the same time, the high level of proficiency that can be reached by individuals with CP might have been overlooked or neglected.

In the current study, we focus on attentional processes that support the performance of high-skilled soccer players with CP who are members of the Dutch CP soccer team. This team has won the Paralympics on several occasions. Participants were asked to perform a dribbling task in conditions with distinct attentional focus. The dribbling task entails the maneuvering of a ball through a series of pylons that form a slalom course by a sequence of short taps or kicks with the inside and outside of one foot. In the *task-irrelevant* focus (i.e., divided attention) condition, participants perform a secondary double task that distracts attention away from the primary dribbling task, whereas participants explicitly monitor the execution of the dribbling task in the *task-relevant* focus condition (i.e., skill-focus attention). The performance of individuals with left and right hemiparesis is compared to scrutinize the mediating effects of hemispheric lesion on these attentional processes. We first discuss the differential roles of task-relevant and task-irrelevant attentional focus in low-skilled and high-skilled typically developing sportsmen. Expectations with respect to high-skilled players with CP are subsequently formulated.

Traditional theories on motor learning postulate that motor skill is initially acquired explicitly via verbally based cognitive processes. As learning proceeds toward more advanced levels, the skill becomes automated or implicitly controlled. Explicit access to the knowledge supporting the skill is unnecessary, difficult, and might even interfere with task performance (Fitts & Posner, 1967). Many contemporary cognitive theories of skill acquisition still consider the cognitive processes to be true demarcations for the distinct stages of learning (Anderson, 1983; Beilock & Carr, 2001; Cleeremans et al., 1998). These theories postulate that performance in the initial cognitive stage is based on declarative knowledge and strongly relies on the availability of working memory (Berry & Broadbent, 1988). Declarative, or explicit, knowledge consists of verbalizable facts and rules about the motor skill that actors consciously use to achieve optimal performance (Abernethy et al., 2007). Because of its limited capacity, working memory can only handle small amounts of declarative knowledge at one time, resulting in performance being executed in a step-by-step fashion and with conscious attention. In the subsequent associative stage, declarative knowledge is gradually transformed into procedural knowledge (e.g., routines and schemas). In the autonomous stage, performance is automated without further need for the involvement of working memory or conscious attention. In this final stage, the individual is said to be a skilled performer.

The different cognitive substrates of performance in the distinct stages have important implications for the effects of attentional focus. Low-skilled performers would benefit from a task-relevant focus in which attention is explicitly directed to the mechanics and regularities of motor performance. However, motor performance would be severely compromised when other tasks impinge on these limited working memory resources, for instance, when a second attention-demanding task is performed concurrently with movement execution. In contrast, motor performance of high-skilled performers would not be negatively affected by a secondary task, because automatized motor performance does not rely on working memory resources. Highly skilled performers do not normally consciously attend to the implicit procedural knowledge. Yet, a task-relevant focus, which prompts attention toward skill execution, brings this implicit procedural knowledge back into working memory. As a result, the skill becomes decomposed into a sequence of smaller units that each requires separate conscious control, which slows down movement execution and increases the likelihood of errors (e.g., at transition between units; Beilock et al., 2002; Masters, 1992). A task-relevant focus is, therefore, expected to affect motor performance adversely in highly skilled performers.

There is ample support for these ideas. For example, Beilock et al. (2002) tested the effects of task-relevant and task-irrelevant focus on the dribbling performance of low- and high-skilled soccer players. Participants dribbled a slalom course while concurrently reporting either a target word from a stream of nouns spoken from a tape recorder (task-irrelevant focus) or the side of the foot that was in contact with the ball upon hearing a tone (task-relevant focus). In line with the ideas outlined above, low-skilled players performed better under the task-relevant condition as compared with the task-irrelevant condition, whereas high-skilled soccer players performed better in the task-irrelevant condition. Beilock et al. (2002) concluded that novices benefit from online attentional monitoring of step-by-step performance, whereas high-level performance is harmed in these conditions (see also, Ford et al., 2005).

At present, not much is known about possible lateralization of attentional processes and working memory. There are indications that damage to the left hemisphere is associated with impairments in the early stages of learning of a motor skill (Kimura, 1977). In addition, Jueptner et al. (1997) found left dorsal prefrontal activity when participants paid attention to what they were doing. These findings suggest that a task-relevant focus of attention to action and, possibly, the reinvestment of declarative knowledge through working memory, is a left hemispheric function.

Converging evidence in young adolescents with CP shows that motor planning, a function for which working memory is a prerequisite, is compromised (Steenbergen & Gordon, 2006). Steenbergen et al. (2004) showed that motor planning was especially impaired in individuals with right hemiparesis (i.e., left-hemisphere damage), suggesting that it is a left-lateralized function. In line with this finding, Mutsaarts et al. (2006) found that young adolescents with congenital left-hemisphere damage had difficulties learning, or were sometimes not able to learn, from their errors on a novel motor task. If we speculate that these effects are mediated by a task-relevant focus, then this would be consistent with the conjecture that attention to action and the reinvestment of procedural knowledge through working memory is more dependent on left-hemispheric contributions.

The aim of the current study is to examine the attentional processes underlying high-skilled motor performance in individuals with hemiparetic CP. Apart from its theoretical value, the results might have implications for the training of these individuals in a sports- (and rehabilitation-) related context. We examined the effects of task-relevant focus (i.e., attention to motor performance) and task-irrelevant focus (i.e., attention to a secondary task) on dribbling performance of expert soccer players with left and right congenital hemiparesis using a design similar to Beilock et al. (2002). Beilock et al. (2002), who studied expert soccer players without neurological damage, found no degraded dribbling performance when performing a secondary irrelevant task. Based on the assumption that the attentional processes supporting high-level performance are similar among expert soccer players with and without brain damage, we expect the same pattern of results in the highly skilled soccer players with hemiparetic cerebral palsy. By contrast, a task-relevant focus is expected to result in a decrement of dribbling performance among these high-skilled players. Soccer players with left and right congenital hemiparesis participated to examine possible lateralization of these processes. If attention processes associated with the reinvestment of procedural knowledge are indeed left lateralized, we expect performance in the task-relevant focus condition to be less adversely affected in individuals with left- than with right-hemispheric damage.

Method

Participants

Participants were members of the Dutch National Cerebral Palsy Soccer team, and they gave informed consent prior to testing. A total of 10 participants were selected (mean age, 22.7 [years]; *SD* 2.7 [years]), 5 with left hemiparesis and 5 with right hemiparesis. We performed the Box and Block test of gross dexterity (Mathiowetz et al., 1985) and the Purdue Pegboard test of fine dexterity (Tiffin, 1968) to establish the laterality of the hemiparetic condition. Foot preference was asked to each participant. Five participants were self-proclaimed right-footed, and five participants were self-proclaimed left-footed, which corresponded to the results on both dexterity tests and their hemiparetic condition (see Table 1). We did not include a control group, because our experimental setup was similar to the one used in Beilock et al. (2002). Therefore, the results of that study with expert soccer players without neurological damage will serve as the control for the current study (see also Ford et al., 2005).

Table 1 Participant Information

	Sex	Diagnosis	Age (y)	BB less affected	BB affected	PP less affected	PP affected
1	male	Left hemiparesis	24.8	66	7	16	0
2	male	Left hemiparesis	19.3	62	52	16	9
3	male	Left hemiparesis	19.4	74	37	17	7
4	male	Left hemiparesis	22.5	68	19	15	1
5	male	Left hemiparesis	24.5	80	27	16	2
6	male	Right hemiparesis	26.7	88	31	16	1
7	male	Right hemiparesis	24.5	78	2	15	0
8	male	Right hemiparesis	22.3	79	41	18	6
9	male	Right hemiparesis	24.0	91	33	18	1
10	male	Right hemiparesis	18.8	72	34	15	1

Abbreviations: BB, Box and Block test; PP, Purdue Pegboard test.

Task

We used the same method and experimental paradigm that was successfully applied by Beilock et al. (2002). The primary task that participants performed consisted of dribbling a ball around a series of 10 pylons that formed a slalom course. The pylons were set 1.5 m apart, resulting in a track length of 15 m. Each participant was tested in a control, a task-relevant focus, and a task-irrelevant focus condition.

Control Condition. Participants were instructed to dribble the slalom course as quickly and accurately as possible.

Task-Relevant Focus Condition. Participants were instructed to dribble the slalom course as quickly and accurately as possible. They were instructed to attend and to be aware of the side of the foot that was in contact with the ball throughout the dribbling trial. A single tone occurred at a random time period on a tape, but on average once every 6 s. The occurrence of these tones was temporally aligned with the occurrence of the target word in the task-irrelevant focus condition. Upon hearing the tone, participants were required to immediately verbally indicate whether the outside or the inside of the foot was in contact with the ball.

Task-Irrelevant Focus Condition. Participants were instructed to dribble the slalom course as quickly and accurately as possible while performing a secondary word-monitoring task that required them to repeat a target word when they heard it. Participants heard tape-recorded, single-syllable Dutch words selected from a list of the most frequently used single-syllable Dutch words in spoken language (*tijd* [time], *man* [man], *jaar* [year], *plaats* [place], *vrouw* [woman], *dag* [day], *werk* [work]). These words were presented at random within 2-s intervals. Prior to this condition, participants were informed of the target word (*jaar*). This target word occurred at random, but on average every three words (*viz*., every 6 s). Upon hearing this word during dribbling, participants were required to repeat this word immediately.

Procedure

Prior to each of the three conditions, participants were instructed about the upcoming condition and performed one practice trial to become familiar with the condition, which was sufficient for all participants. In each condition, three trials were performed in immediate succession yielding a total of nine trials for each participant. The order of the three conditions was randomized across the 10 participants. A small rest period followed each condition. At the start of the trial, the experimenter started the tape recorder on which the sequenced words/tones were recorded. Every sequence started with a prerecorded “go” signal that signified the start of the trial. This “go” signal was also used in the control condition.

Data Analysis

The experiment was recorded with a digital video camera with a sample frequency of 25 Hz. Two measures were extracted off-line from the video record: (a) time to complete the slalom course (movement time, *MT*) and (b) number of verbal errors. The latter were either related to the wrong side of the foot (task-relevant focus condition), or not responding to the target word, or responding to the wrong word (task-irrelevant focus condition). To normalize for dribbling speed across participants, we calculated difference scores between the mean *MT* of the trials in the control condition and the mean *MT* of the trials in each of the attentional-focus conditions (see Ford et al., 2005, for a similar method). The difference scores were analyzed using two-tailed t tests, both for the total group (N = 10) and for each group separately (players with left and right hemiparesis). Cohen's d was used as the measure of effect size. Following Cohen (1988), a d between 0.2 and 0.5 was defined as small, a d between 0.5 and 0.8 as moderate, and a d of 0.8 or higher was considered to be large.

Results

Movement Time

Figure 1 displays the actual mean movement times (*MT*s) for all participants as a function of condition. On average, the participants took 11.2 s to complete the slalom course in the control condition, which is 0.74 s for each meter (or 1.1 s for each pylon). As a comparison, the skilled nonhandicapped participants in previous studies took 0.65s for each meter or 1.1 s for each pylon (cf., Beilock et al., 2002), and 2.08 s for each meter or 1.4 s for each pylon (Ford et al., 2005), which underlines the high levels of dribbling skill of the participants with CP in the current study.

Attentional Focus Comparisons: All Participants (N = 10). The *MT* difference score for the control and task-relevant focus conditions was significantly different from 0 (t [9] = 5.53, p < .001, d = 0.41), indicating that focusing attention on movement execution slowed down dribbling speed. By contrast, the *MT* difference score

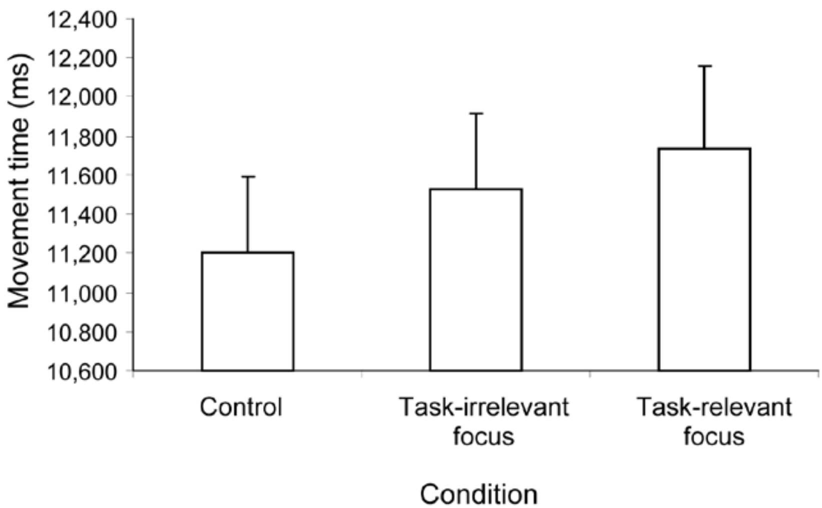

Figure 1 — Average movement time as a function of condition for the whole group (N = 10). Error bars represent between-participant variability (*SE*s).

for the control and task-irrelevant focus condition was not significantly different from 0 (t [9] = 1.52; see Figure 1).

Attentional Focus Comparisons: Participants With Left Hemiparesis (n = 5). Figures 2 and 3 illustrate the *MT* difference scores for the control condition and each of attentional-focus manipulation conditions for the players with left hemiparesis.

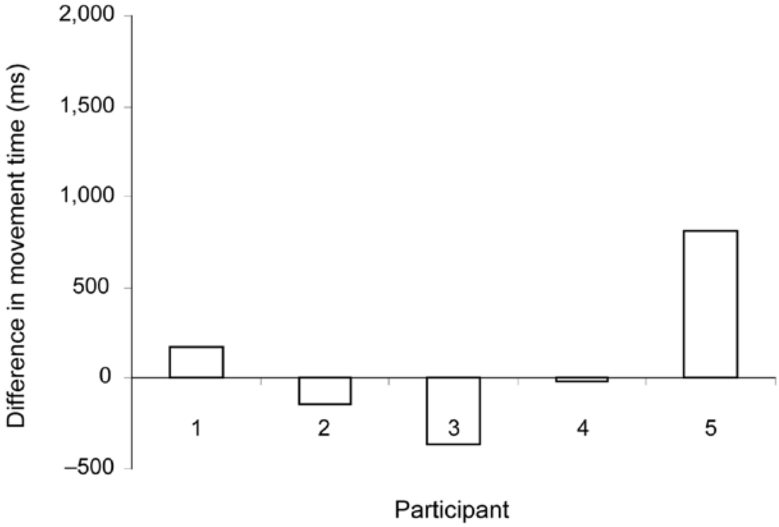

Figure 2 — Movement-time differences between the control and the task-irrelevant focus conditions for participants with left hemiparesis. Positive values indicate slowing down in the attention-manipulation condition relative to the control condition.

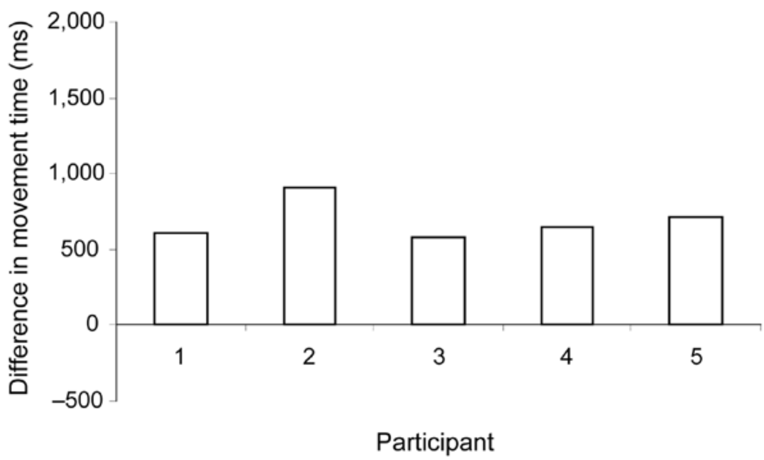

Figure 3 — Movement-time differences between the control condition and the task-relevant focus condition for participants with left hemiparesis. Positive values indicate slowing down in the attention-manipulation condition relative to the control condition.

Positive values indicate a decrement in *MT* in comparison to the control condition without attention instruction. As shown in the lower panel, all five participants slowed down dribbling speed under the task-relevant focus condition, producing a significant effect on the *MT* difference score ($t[4] = 11.60$, $p < .01$, $d = 0.42$). By contrast, the *MT* difference score for the control and task-irrelevant focus conditions revealed large individual differences (Figure 2) and did not differ from 0 (t $[4] = 0.66$).

Attentional Focus Comparisons: Participants With Right Hemiparesis (n = 5). Figures 4 and 5 display the attention-focus manipulation effects for the players with right hemiparesis. Three of the participants showed a slowing down under the task-relevant focus condition, which resulted in a nonsignificant effect for the *MT* difference score (t $[4] = 2.34$, $p = .08$, $d = 0.64$; Figure 5). There was no systematic effect of the task-irrelevant focus (t $[4] = 1.49$; Figure 5).

Between-Group Comparisons. Between-group comparisons suggest that the magnitude of the slowing down in the task-relevant focus condition is larger among the players with left hemiparesis than among players with right hemiparesis. This difference was not found to reach conventional levels of statistical significance (t $[8] = 1.92$; $p = .09$, $d = 1.21$), but the large effect size clearly indicates that the difference is of (practical) significance. The effect of the task-irrelevant focus manipulation did not differ between the two groups (t $[8] = 1.09$).

Errors

Analysis of the video record showed that none of the participants made any verbal reporting errors in the attentional-focus conditions, yielding statistical analysis of this variable superfluous.

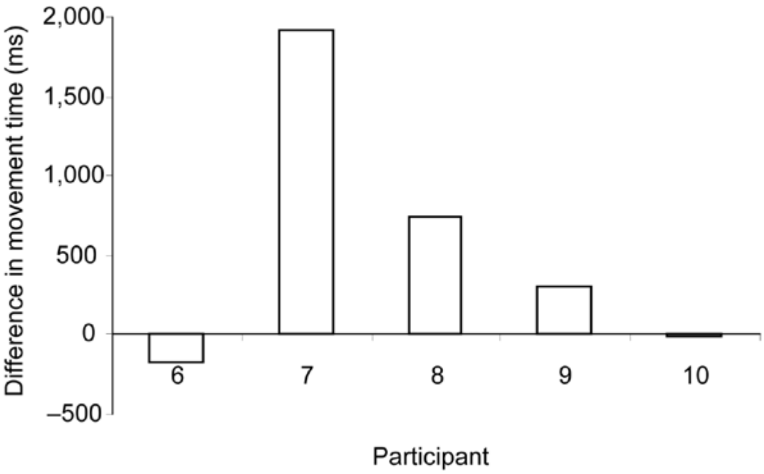

Figure 4 — Movement time differences between the control and the task-irrelevant focus conditions for participants with right hemiparesis. Positive values indicate slowing down in the attention-manipulation condition relative to the control condition.

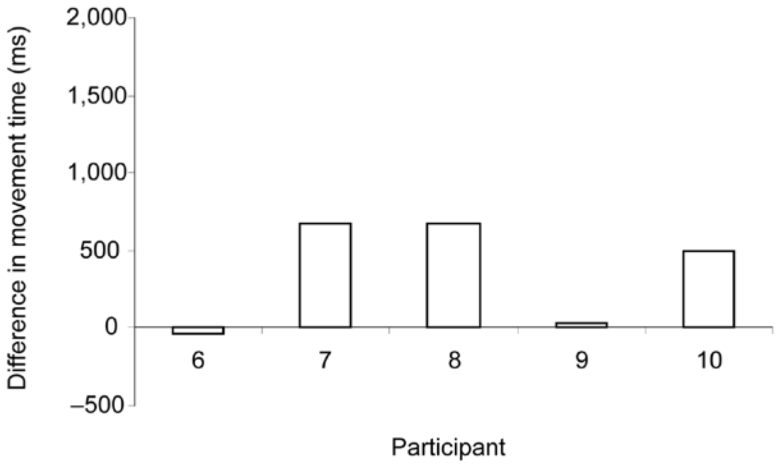

Figure 5 — Movement time differences between the control condition and the task-relevant focus condition for participants with right hemiparesis. Positive values indicate slowing down in the attention-manipulation condition relative to the control condition.

Discussion

We studied the attentional processes supporting dribbling performance in high-skilled soccer players with hemiparetic CP. As members of the Dutch CP soccer team, they constitute a small but exceptional group of world-class athletes. In fact, and despite the impairment, their dribbling speed compares favorably with the high-skilled players without neurological disorders that participated in similar studies (Beilock et al., 2002; Ford et al., 2005). We must emphasize, however, that investigations concerning elite athletes are often limited in terms of sample size, the current study being no exception. Therefore, our conclusions should be taken with appropriate caution.

Previous research in high-skilled sportsmen without neurological disorders has found that performance is harmed when attention is directed to task execution (Ford et al., 2005). This deautomatization is believed to reflect that implicit procedural knowledge is brought back into working memory. The task is broken down into smaller units, each of which requires the conscious control that results in disruption and a slowing down in performance (Masters, 1992). Conversely, there is some evidence that high-skilled performers may even benefit from conditions that divert attention away from task execution (e.g., Beilock & Carr, 2001; Beilock et al., 2002), although other studies have failed to show such a benefit (e.g., Ford et al., 2005; Gray, 2004).

As a group, the high-skilled soccer players with hemiparetic CP showed similar effects of attentional-focus conditions as those observed in high-skilled players without neurological disorders. Task-relevant focus of attention had a negative effect on dribbling time, and task-irrelevant focus of attention did not result in any significant change in performance (Beilock et al., 2001; Ford et al., 2005). This would suggest that high-skilled performance of individuals with and without congenital brain damage is supported by similar attentional processes. Stated differently, congenital brain damage appears not to have an effect on the attentional processes underlying high-skilled performance.

We also observed individual differences that might suggest different attentional mechanisms among participants with left and right hemiparesis. All five soccer players with left hemiparesis (i.e., damage to the right hemisphere) showed adverse effects of a task-relevant focus that are similar to those reported for high-skilled players without neurological disorders. However, the effects of a task-relevant focus were less consistent among players with right hemiparesis (i.e., left-hemisphere damage) as dribbling speed was not adversely affected in at least two players. In addition, the magnitude of the negative effects of task-irrelevant focus might have been larger in the group of players with left hemiparesis as compared with the group of players with right hemiparesis. Although this difference just failed to reach conventional levels of statistical significance, the large effect size suggests that it is of practical significance. Intriguingly, these findings are in alignment with arguments that the reinvestment of procedural knowledge is a left-lateralized function. Damage to the left hemisphere would obviate or reduce reinvestment. Consequently, the adverse effects on task execution are expected to be diminished, and that is exactly what we found for the soccer players with right hemiparetic CP.

The differential effect of task-relevant focus for high-skilled players with hemiparetic CP cannot be explained by an inability of the players with right hemiparesis to direct attention to movement execution per se. That would have resulted in more errors reporting the side of the foot that contacted the ball. Both groups were errorless, however. Therefore, the less adverse effects of task-relevant focus among players with right hemiparesis are likely due to a disruption in reinvestment. In fact, the results for the players with right hemiparetic CP represent a rare case of a neurological deficit having a relatively beneficial influence on task performance. A similar positive effect of a neurological deficit on the performance of bimanual coordination is observed in patients without an intact corpus callosum who do not suffer from the well-documented interference effects when drawing circles with one hand and squares with the other.

A final word of caution about the verbal errors needs to be made here. The absence of verbal errors may also indicate that participants prioritized giving a correct verbal response over response speed. Because of the low temporal resolution of the video record (25Hz) in relation to the quick verbal response by the participants, this form of speed-accuracy trade-off could not be reliably assessed in this study. However, this possible trade-off certainly deserves further study to exclude the possibility that the observed variability in dribbling speed is related to differences in the attentional load of the task-relevant and task-irrelevant focus conditions.

Eventually, our findings may have implications for training and coaching individuals with CP in a sports context. Instructions that induce an explicit step-by-step monitoring of task execution should probably be avoided for high-skilled sportsmen with left hemiparetic CP, because this is likely to have detrimental effects for their performance. Rather, a more implicit mode of instruction would be more appropriate (Masters, 1992). For participants with right hemiparesis, explicit instructions that increase the likelihood of conscious processing will be less problematic.

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