Title: Implicit learning increases shot accuracy of football players when making strategic decisions during penalty kicking

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Abstract

Implicit learning has been proposed to improve athletes' performance in dual-task situations. Yet, only a few studies tested this with a sports-relevant dual-task. Hence, the current study aimed to compare the effects of implicit and explicit training methods on penalty kicking performance. Twenty skilled football players were divided in two training groups and took part in a practice phase to improve kicking accuracy (i.e., without a goalkeeper) and in a post-test in order to check penalty kick performance (i.e., accuracy including a decision to kick to the side opposite the goalkeeper's dive). Results found that the implicit and explicit training method resulted in similar levels of decision-making, but after implicit training this was achieved with higher kicking accuracy. Additionally, applications for football players and coaches are discussed.

Highlights

- Implicit and explicit kicking training result in similar levels of decision-making skill
- Implicit training results in higher kicking accuracy compared to explicit training
- Maintaining the level of decision-making adversely affects kick accuracy after explicit training

Keywords: implicit learning, dual-tasking, penalty kick, decision making, ecological validity

1. Introduction

The human capacity to perceive the intricacies of the environment and make appropriate decisions within an instant is astonishing. This capacity is especially developed in elite athletes, who –unlike less skilled players– usually can maintain perceptual and performance accuracy despite the many (unexpected) changes and high pressure, which characterize competitive sports situations (Mann, Williams, Ward & Janelle, 2007; Sibley & Etnier, 2004). In fact, competitive performance situations typically require the athlete to address multiple tasks simultaneously (Ripoll, Kerlirzin, Stein & Reine, 1995). Movement automaticity is a pertinent factor in the athlete's capacity to execute multiple tasks. For instance, it is by virtue of the automatization of action that skilled football players can at the same time decide whether to pass the ball to a teammate, shoot on goal, or dexterously dribble by opponents *and* maintain control over the ball. By contrast, less skilled players must attend to their actions and the ball, requiring a good amount of cognitive resources. Consequently, at the same timing making strategic decisions more likely results in overloading, hampering the skilled players' ability to produce accurate actions.

An effective way to accelerate automaticity of action is through implicit learning. It has been shown that following implicit learning methods, performance decrements caused by simultaneously executing a second task (e.g., backward counting or tone identification) are significantly reduced compared to explicit learning methods (Lam, Maxwell & Master, 2009; Maxwell, Masters, Kerr & Weedon, 2001; Poolton, Masters & Maxwell, 2005). Explicit learning methods stimulate the accumulation of declarative knowledge about how to move, and result in a prolonged reliance on conscious control in action execution. Instead, implicit learning methods directly promote the built-up of procedural knowledge by circumventing working memory such that the accumulation of declarative knowledge is minimized (e.g., Masters, 1992; Masters & Maxwell, 2004; Maxwell, Masters & Eves, 2003). The resulting reduction in working memory involvement allows for the concurrent execution of additional tasks. Accordingly, action execution following implicit learning has been argued to be more robust under dual tasks situations than after explicit learning (MacMahon & Masters, 2002; Masters, Poolton, Maxwell & Raab, 2008). Additionally, implicit methods result in better performance maintenance in high-pressure situations (Masters, 1992; Maxwell, Masters & Eves, 2000).

A sport situation par excellence that can involve both dual tasking and high-pressure is the penalty kick in football, if, that is, the penalty taker adopts a goalkeeper-dependent strategy. In the goalkeeper-dependent strategy, the kicker intends to direct the ball to the side opposite of the goalkeeper's dive (van der Kamp, 2006). A successful penalty kick requires that the penalty taker produces an accurate, well-controlled kicking action *and concurrently* accurately watches the goalkeeper and makes strategic decisions to which side to kick the ball. In other words, it is a defining feature of the goalkeeper-dependent strategy that a conscious decision is made while kicking. This makes the goalkeeper-dependent strategy essentially a dual task.

It is to be expected that practicing kicking skill and accuracy in an implicit manner will benefit penalty kick performance with a goalkeeper-dependent strategy compared to performance following an explicit intervention to improve kicking accuracy. This conjecture, however, is largely based on studies that investigated the effects of dual tasking using a second task that is largely irrelevant to sports situations (e.g., participants respond to auditory tones or generate letters in a random sequence, see Beilock, Wierenga & Carr, 2002; Carr, Etnier & Fischer, 2013; Lam et al., 2009). In these studies, dual tasking serves to assess action automaticity. That is, dual tasking helps to infer the amount of conscious control a participant needs to maintain action performance levels (Lam, Maxwell, & Masters, 2010). The primary motor action is considered automatized and without need of conscious control, if concurrent performance with a second task does not result in performance decrements relative to single task performance (Abernethy, 1988). Although many researchers have examined implicit learning methods for sports-related tasks, only few studies included the effects of sports-relevant concurrent tasks to test the automaticity of action (Masters et al., 2008; Raab, Masters & Maxwell, 2005).

One example is the study by Masters et al. (2008). These authors investigated the resilience of action against dual tasking following implicit and explicit learning interventions using decision-making in a complex sport task. Participants first practiced a table tennis shot either implicitly (i.e., analogy learning) or explicitly (i.e., six step-by-step verbal instructions) and were then tested in two decision-making conditions. The low-complexity condition required participants to aim balls to left or right side depending on their colour, while in high-complexity condition the regularity between ball colour and side alternated. The participants' ability to accurately hit the ball to the correct side was only jeopardized for the explicit learners in the high-complexity condition. The implicit learners maintained action performance levels in both decision-making conditions. This suggests that following implicit learning participants had more cognitive resources available for decision-making, presumably due to a higher degree of automatization of the table tennis shot.

Our aim here was to investigate whether implicit learning methods, which aim to improve kicking accuracy, promote –after practice- kicking accuracy when adopting the goalkeeper-dependent strategy, which requires players to make strategic decisions regarding the side to shoot. More in general, we tested the benefits of implicit learning in the context of a sport-relevant dual task. As briefly mentioned above, football players can either adopt a goalkeeper-independent or goalkeeper-dependent strategy when taking a penalty kick (van der Kamp, 2006). On the one hand, in the goalkeeper-independent strategy, the kicker decides where to aim the ball before starting the run-up to the ball and holds on to that decision irrespective of the goalkeeper's actions. In the goalkeeper-dependent strategy, on the other hand, the kicker intends to kick to side opposite of the side the goalkeeper is going to dive. The final decision on the side to kick the ball thus depends on the goalkeeper's actions. Accordingly, the kicker must extract information from the goalkeeper's action during the run-up and the execution of the kick to decide kick direction. Anticipating and deciding where to kick at the same time as producing the run-up and the kick action defines taking a penalty kick as a dual-task. Morya, Ranvaud and Pinheiro (2003) suggested that when the time available to make the decision is reduced, for instance because the goalkeeper starts moving late, this adversely affects a kicker's ability to accurately direct the ball to the side opposite to the goalkeepers dive. Indeed, it has been reported for in-situ penalty kicking situations that penalty takers require approximately 500-600 ms to accurately and forcefully kick the ball to the intended side; with less time available decision making and/or kicking accuracy was jeopardized (Bowtell, King & Pain, 2009; van der Kamp, 2006, 2011). If implicit learning methods indeed lead to a reduction in the contribution of cognitive resources to produce actions, then the implicit practice of kicking accuracy might diminish the adverse affects on decision-making and kicking accuracy.

In sum, the current study examined whether an implicit learning method enhances kicking accuracy and/or decision making among penalty takers who adopt a goalkeeper-dependent strategy in comparison to explicit methods. To this end, two groups of high skilled football players practiced kicking accuracy in either an implicit or an explicit manner. We manipulated the degree of implicit and explicit learning during three practice sessions by varying the order and saliency of changes in task difficulty, which is (partly) based on validated protocols that induce different amount of errors during practice (i.e., errorless learning, Maxwell et al. 2001). Task difficulty was manipulated by using differently sized target areas (cf. Poolton, et al., 2005). Accordingly, the participants that underwent the implicit method started each session with low task difficulty (i.e., large target area) with task difficulty gradually increasing (i.e., small target areas) toward the end of the sessions. In contrast, participants who followed the explicit method were presented with continuous changes in task difficulty, with differences between subsequent trials being so large that they were immediately noticed.[1] The total amount of variability in task difficulty, however, was the same in the groups. By starting easy and then increasing task difficulty gradually, the implicit method aims to keep kicking errors to a minimum. Typically, the subtle changes in task difficulty may not always be consciously noticed. It is presumed that this way learners are less likely to form and test hypotheses and hence build-up less declarative knowledge as compared to the explicit method that involves random and highly salient changes in task difficulty (Maxwell et al. 2001; Poolton et al., 2005). The later salient switches in task difficulty, and the increased number of errors early in practice, are likely to enhance deliberate attempts to improve kicking accuracy (see also Lee & Magill, 1983; Lee, Wulf & Schmidt, 1992; Shea & Morgan, 1979). We hypothesized that participants who practiced implicitly would show increased kicking accuracy and/or decision-making compared to participants who practiced explicitly.

2. Methods

2.1 Participants

[1] These methods are variants of errorless and errorful learning protocols respectively. However, rather than decreasing task difficulty gradually as in errorful learning, we choose to maximize task difficulty between consecutive trials to increase the saliency of changes in task difficulty. We reasoned that doing so would further increase conscious processing (Lee, Wulf & Schmidt, 1992).

A priori power calculation using G*Power 3.1.7 for a MANOVA with repeated measures[2] (i.e., effect size f = 0.25, α = 0.05, power = 0.80) indicated a sample size exceeding 200 participants. This is an impractical high number given the difficulty recruiting high skilled players. Hence, we also did power calculations for an ANOVA with repeated measures to estimate the minimum number of players to be recruited for participation, because this would be the intended follow up test for a MANOVA. This calculation indicated a minimum sample size of 20 participants. Twenty female high skilled footballers (mean age = 17.3; SD = 2.8), who played competitively in youth professional and amateur leagues, volunteered to take part in the experiment. To be able to recruit a sufficient number of participants, the experiment was conducted at two locations by the same experimenter (the first author) with identical material and apparatus. In Amsterdam, The Netherlands, fourteen players of the Dutch Talent Team participated, and in São Paulo, Brazil, an additional six players of the University of São Paulo volunteered.[3] Approval of the local ethical committees was obtained, and all participants (and if needed, their parents) provided written informed consent prior to testing.

2.2 Apparatus

In line with the FIFA regulations, the participants took penalty kicks in an indoor sports hall from a distance of 11 m to a wall on which a football goal (7.32 m x 2.44m) was projected. A regular size 5 ball was used. Red target circles were projected in the left and right top corners of the goal, with their midpoint 0.8 m below and 0.9 m from the nearest cross bar. In international competition, goalkeepers almost never save penalty kicks, which are aimed near these locations (approx. within 0.8 m) with sufficient speed (Armatas, Yiannakos,

[2] All power analyses were based on analyses of variance with a between and a within factor. However, subsequent analysis showed that manipulation underlying the within factor (i.e. pressure manipulation) was not successful. Consequently, the final analyses did not include the within factor (for more details check the following section: 2.3. Procedures and Design)

[3] We checked for differences between the Dutch and Brazilian participants, but did not find any.

Papadopoulou, & Galazoulas, 2007; Morya, Bigatão, Lees, & Ranvaud, 2003; see Navarro, van der Kamp, Ranvaud & Savelsbergh, 2013). In the test phase, the target circles were always of the same size (i.e., 0.22 m in diameter, the size of a regular football), whereas during the practice phase the target circles varied in diameter between 0.22 and 0.80 m with 0.02 m increments. The target circles were visible throughout the penalty kick (i.e., prior and during the run-up, and until after the ball hit the wall).

Additionally, in the test phase, but not in the practice phase, an animated goalkeeper was projected at the centre of the goal line. In 90% of the test trials, the animated goalkeeper dived either to the right or left side of the goal. In the remaining 10%, the goalkeeper stood stationary and did not move. After the goalkeeper had started the dive, only the target circle (i.e., 0.22 m in diameter) to the side opposite of the goalkeeper's dive remained visible, the second circle disappeared (e.g., when the animated goalkeeper moved to the right, the right circle disappeared and the left circle remained visible). At the start of each trial the goalkeeper stood stationary at the centre of the goal line. During the participant's run-up to the ball, the experimenter started the goalkeeper's dive by triggering the animation via a keyboard press. Little pins in the field, invisible to the participants, indicated 2.4 m, 1.6 m and 0.8 m distance to the ball. The experimenter triggered the animation, when the participant in her run-up arrived at one these positions (see below). E-prime 2.0 Pro software was used to control the animation.

A pinhead microphone was placed 50 cm next to the ball, the signal of which was input to E-prime and served to determine the instant of kicker ball contact (i.e., indicated by sudden peak in the auditory signal). E-prime 2.0 Pro thus allowed us to synchronize the start of the goalkeeper dive (i.e., the moment the experimenter pressed the key) and the moment the participant contacted the ball and to calculate amount of time the participant had available to respond to the goalkeeper's dive.

Finally, a full HD digital video camera (CREATIVE VADO 25Hz) was positioned 0.8 m behind and 1.5 m to the side of the penalty mark and recorded the goalmouth. The video recordings were analysed off-line to determine kick accuracy.

2.3 Procedures and design

The study consisted of a practice and a (post) test phase[4]. Both phases started with six warm-up trials during which participants took penalty kicks at an otherwise empty goal (i.e., no target circles and goalkeeper). Before the start of the practice phase, participants were randomly assigned (i.e., using the Excel randomization function) to one of two groups: the low saliency group (LS-group), in which changes in task-difficulty were gradual and had low saliency, and a high saliency group (HS-group), in which changes in task-difficulty were large and highly salient. The practice phase consisted of three sessions taking place on separate days. During each session, the LS-group received a practice protocol within which the size of the target circle was systematically decreased 0.02 m from one trial to the next, starting from the largest circle (i.e., 0.80 m) to the smallest circle (0.22 m). The HS-group received a protocol during which, within each session, the target circles of different size were presented in a random order, but always with a clearly noticeable size difference of at least 10 cm from one presentation to the next. The two groups practiced with target circles of the same size but presented in a different sequence; this way, the changes in target size, and thus task difficulty, were much more salient for the HS-group than for the LS-group. Participants had to start their run-up 3.5 m behind the ball. They were instructed to kick the ball to the designated target

[4] As is typically the case in implicit motor learning studies, we purposely omitted the pre-test, because it may interfere with subsequent implicit motor learning. That is, errors made in the pre-test may or may not lead to hypothesis testing, which would introduce an accumulation of declarative knowledge. This would invalidate participants in the implicit group as implicit learners (Masters, 1992; Maxwell et al., 2001).

circle as accurately as possible and sufficiently powerful. Within one practice session, participants took 60 penalties in total, divided in two blocks of 30 each. In the first block, participants aimed to the target circle on one side of the goal (i.e., either the left or the right side). In the second block, they aimed to the target at the other side of the goal (i.e., either the right or left side of the goal). The order of blocks was counterbalanced across participants and sessions. The order in which the different sized target circles were presented within a block was the same across blocks.

In the test phase, participants took 60 penalty kicks on the projected target circle (0.22 m in diameter) that were now projected together with the animated goalkeeper. Originally, the test phase was conceived as two counterbalanced conditions, 30 kicks in a low-pressure and 30 kicks in a high-pressure condition. In the low-pressure condition, the participants were simply instructed regarding the task goal. In the high-pressure condition, however, several procedures, in addition to instructions regarding the task goal, were followed to increase participants' anxiety level. Participants were told that the test assesses their decision making capacity; that a ranking based on their penalty taking skill would be circulated among players and the coach; and that a prize would be awarded to the best penalty taker (see Wilson, Wood & Vine, 2009). However, the Mental Readiness Form-3 (MRF-3; Krane, 1994) indicated that participants' anxiety in the high-pressure condition was not significantly[5] increased compared to the low-pressure condition. We therefore combined the two conditions for further analyses. The animated goalkeeper dived in 90% of the trials, but did not move in remaining 10% of the trials. Participants were instructed to aim for the target circle opposite to the side of the goalkeeper's dive, or to choose a target of their own choice in the case the goalkeeper would not move (i.e., in this condition, both target circles remained visible throughout the run-up.).

[5] An ANOVA with repeated measures with group as between and pressure as within variables did not reveal significant differences in anxiety score for pressure, $F(1, 18) = 0.33$, $p = .86$, $\eta_p^2 = .003$, and group $F(1, 18) = 1.71$, $p = .22$, $\eta_p^2 = .13$.

In other words, compared to the practice trials, in the test trials a concurrent decision-making aspect was added to the task. Participants had to start the run-up 3.5 m behind the ball and were told to aim as accurately as possible and sufficiently powerful. In the 54 trials that the goalkeeper dived, half were to the left and half to the right in a random order. The experimenter triggered the animation when the participant was at one of three different distances (indicated by the pins) from the ball: (i) at 2.4 m from the ball (i.e., early in the run-up at approx. 3 steps from the ball); (ii) 1.6 m from the ball (i.e., in the middle of the run-up, at approx. 2 steps); and (iii) at 0.8 m from the ball (i.e., late in the run-up, at 1 step)(van der Kamp, 2006). The three distances at which the goalkeeper started to dive were randomized during the test. For each distance, the goalkeeper dived a total of nine times to the left, nine times to the right and remained stationary twice.

2.4 Data Analysis

In the absence of a pre-test, it is important to verify whether the two groups performed at approximately the same level when they start practicing (Masters, 1992). To this end, the video-recordings of the first six largest targets within the first block of the first practice session were analysed off-line. For the LS-group, these were the first six penalty kicks, while for the HS-group the six largest target sizes were all within the first fifteen penalty kicks. We determined the percentage of trials (out of six) that landed in the goalmouth, the percentage of trials that hit the target circle, and finally, the accuracy or the average distance the ball landed from the centre of the target (in cm)(i.e., balls shot outside the goalmouth were excluded from this final analysis). The dependent variables were submitted to a multivariate analysis of variance (MANOVA) with group as a between factor.

To determine if the two groups showed different amounts of errors during the practice phase but improved performance across practice sessions, the percentage of target hits was submitted to a ANOVA with group as a between factor and session as a within factor.

For the test phase, we first determined the actual times the participants had available to respond to the goalkeeper, because decision-making and kick accuracy have been found to be a function of time available, rather than distance (Morya et al., 2003; van der Kamp, 2006). To this end, we determined for each trial the actual times between the start of the goalkeeper's dive and the moment of foot–ball contact. The trials were categorized based on the actual times that participants had available to make decision and perform the kick: early in the run-up, more than 850 ms before ball contact; middle, between 500 and 850 ms before ball contact; and, late, less than 500 ms before ball contact (van der Kamp, 2006, 2011).[6] We also determined the percentage of goalmouth hits, the percentage of target hits, and the accuracy or the average distance between the ball's landing location and the centre of the target (in cm). The latter was calculated relative to the nearest target (i.e., if the ball was shot to the wrong side, the distance to incorrect target circle was determined, presuming this was the target the participant aimed for) using dedicated tools from the Kinovea video-analysis software. Finally, we determined, as the measure for decision-making, the percentage of kicks that were shot to the correct side (i.e., the side opposite to the goalkeeper's dive), irrespective of whether if was inside or outside the goalmouth. The trials (10% of the total) during which the goalkeeper did not move were considered as catch trials and not analysed.

The dependent measures were all submitted to a MANOVA with group as between factor and time (early, middle, late) as within factor, which were followed-up with one-way ANOVAs. We adopted $\alpha \leq .05$ as the significance level. In the case that the sphericity

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[6] To verify that participants contributed an equal amount of trials to each time category, an ANOVA with group as between and time as within factor was performed. No significant differences were found for time, $F(1, 18) = 0.63$, $p = .80$, $\eta_p^2 = .004$) and group, $F(1, 18) = .96$, $p > .34$, $\eta_p^2 = .06$.

assumption was violated, the Huynh-Feldt adjustments of the p-values are reported. Post-hoc pairwise comparisons were conducted using *t* tests Bonferroni corrections where appropriate; Cohen's *d* (i.e., with *d*'s of 0.2, 0.5 and 0.8 delineating small, medium and large effect sizes, respectively), and partial eta squared (η_p^2) were used as measures for effect size (i.e., with η_p^2's of 0.01, 0.06 and 0.14 delineating small, medium and large effect sizes, respectively). All data analysis was performed using SPSS (version 22).

3. Results

3.1 Practice phase

Table 1 shows that performances at the start of practice (i.e., the first six trials to the largest targets) of the LS-group and HS-group were of approximately similar level. Accordingly, the MANOVA with the percentage of goalmouth hits, the percentage of target hits and accuracy (cm) as dependent variables did not reveal significant differences between groups, Pillai's Trace $V = .37$, $F(1, 18) = 2.36$, $p > .05$, $\eta_p^2 = .37$.[7] However, consideration of the performance across the entire practice phase did indicate performance differences (see Figure 1). The ANOVA on the percentage of target hits revealed a significant effect for session, $F(1,18) = 6.66$, $p = .005$ $\eta_p^2 = .88$, and an almost significant main effect for group, $F(1, 18) = 4.42$, $p = .057$, $\eta_p^2 = .27$. The interaction of session by group was not significant, $F(1, 18) = 2.06$, $p > .05$, $\eta_p^2 = .38$. Post hoc indicated that participants hit more targets in practice session 3 than in session 1, $t(18) = 3.72$, $p = 0.003$. No other comparisons were found significant. Finally, the LS-group tended to score more hits than the HS-group.

[7] An anonymous reviewer pointed out that this does not definitely rule out that there were no differences in performance at the start of practice. It is difficult to gauge what the actual initial performances were, since the rate of improvement may have been different.

Table 1

Figure 1

3.2 Test phase

Table 2 reports the percentage of kicks directed to the correct side (i.e., decision-making), the percentage of goalmouth hits, the percentage of target hits and accuracy (i.e., kicking performance) as a function of time available at the moment the goalkeeper started diving. The MANOVA indicated significant effects for group, Pillai's Trace $V = .17$, $F(1, 18) = 2.46$, $p = .05$, $\eta_p^2 = .16$, and time, Pillai's Trace $V = .76$, $F(1, 18) = 7.98$, $p < .0001$, $\eta_p^2 = .38$), but no significant interaction effect. Subsequent one-way ANOVAs for the separate dependent variables indicated that the significant difference between groups was caused by accuracy, $F(1,18) = 8.99$, $p = .004$, $\eta_p^2 = 0.14$, with the LS-group being significantly more accurate than the HS-group. The two remaining coarser performance measures and decision-making were not significantly different between groups. For time, the follow-up one-way ANOVA only showed a significant difference for the percentage of kicks directed to the correct side, $F(1,18) = 70.8$, $p < .001$, $\eta_p^2 = 0.72$. Post hoc comparisons revealed that the percentage of kicks to the correct side was higher early in the run-up (M = 96%, SD = 6%, [91%; 100%]) than in the middle of the run-up (M =73%, SD = 12%, [69%; 78%]), which in turn was higher than when the goalkeeper dived late (M =57%, SD = 12%, [52%; 61%]).

Table 2

4. Discussion

The present study specifically investigated whether an implicit training method increases decision-making and/or kicking accuracy among penalty takers using a goalkeeper-dependent strategy in comparison to an explicit learning method. More in general, it tested the purported benefits of implicit learning methods for performing in dual-task situations, using a sport-relevant second task. To induce implicit and explicit learning, we manipulated the order and saliency of changes in task difficulty in three separate practice sessions without a goalkeeper (cf. Maxwell et al., 2001). In the test following practice, we introduced an (animated) goalkeeper and instructed players to aim the ball to the target opposite the side of the goalkeeper's dive.

As reported previously (e.g., van der Kamp, 2006, 2011), with less time available penalty kick performance degrades, especially with respect to decision-making. Similarly, in the current study, both groups showed excellent performance (i.e., 94-98% of the kicks were directed to the correct side) with more than 850 ms available to decide and produce the kick. However, when the time available was reduced to less than 500ms, both groups performed only slightly better than chance level (i.e., 56-57% of the kicks were directed to the correct side). Research has suggested that goalkeepers who save more penalty kicks tend to wait longer before starting their dive (Savelsbergh, van der Kamp, Williams & Ford, 2005). Perhaps, the possibility that goalkeepers start moving late explains why only 10 to 15% of professional (male) football players adopt the goalkeeper-dependent strategy in competition, even though the success rates are the same as when adopting a goalkeeper-independent strategy (Noël, Furley, van der Kamp, Dicks & Memmert, 2015). Importantly, the (prioritized) decision-making performance in the two groups was similar; yet, the players who had practiced under the implicit protocol showed superior kicking accuracy during penalty taking compared to players who trained more explicitly. These findings are consistent with the hypothesis that after implicit learning, performance absorbs less cognitive resources and therefore allows for better performance in dual-task situations, not only when the second task is artificial but also for a second task that is sports-relevant. In contrast, following explicit learning, which promotes conscious control and monitoring of movement execution, participants appear to have relied more on working memory resources, resulting in less accurate motor performance in dual-task situations, such as when decisions must be made in response to the environment.

As observed previously (e.g., van der Kamp, 2006, 2011), with less time available penalty kick performance degrades, most clearly and significantly for decision-making. We did hypothesize that this performance decrease would be more pronounced after an explicit training, but both groups were equally affected by increasing time pressure. Hence, under the current conditions there is no evidence for a change in working memory load during the unfolding of the run-up. We note that this conclusion contradicts earlier work by Carr et al., (2013), which reports that attentional demands are highest early in the run-up. Carr et al. used a variant of the probe-reaction time paradigm, and showed that response times to auditory stimuli (i.e., a sport-irrelevant dual task) were slower at the start of the run-up. They argued that this is likely to reflect motor planning (of the final steps to positioning oneself relative to the ball). Note, however, that participants did not face a goalkeeper, but were free to select scoring zones, and thus adopted a goalkeeper-independent strategy. Possibly, the load on cognitive resources is differently distributed during the run-up in the two penalty-taking strategies.

4.1 Limitations and future challenges

During practice the degree of implicit and explicit learning was manipulated by varying the order and saliency of the changes in task difficulty. The rationale is that a non-salient gradual increase in task difficulty results in fewer errors and fewer concomitant hypothesis testing than large and salient changes in task difficulty, and hence, reduces the accumulation of explicit knowledge. Although we confirmed that the protocol tended to evoke different amounts of errors, we cannot prove that this also resulted in different degrees of implicit and explicit learning.[8] A verbal-recall protocol, in which the participants report all the rules and facts they regard important for accurate performance, would have substantiated that claim, but we refrained from doing so, because during preparation it appeared that the high skilled players had already a large pool of (generic) knowledge (perhaps also based on practicing other type of kicks, such as, the free-kick). This been said, the practical advantages of the low-saliency practice protocol are clear, even if further research would show they cannot be (fully) attributed to implicit learning. Possibly, further technological advances will allow for gauging EEG-synchronization between verbal and premotor regions as a yardstick for explicit knowledge accumulation during practice (Zhu et al., 2010)

In competitive situations, the strongest performance-debilitating factor in penalty taking is performance pressure (Jordet, Hartman, Visscher & Lemmink, 2007). Performance after implicit learning is typically shown to be more robust against these debilitating circumstances than performance after explicit learning (Masters, 1992; Masters & Maxwell, 2008). In fact, we intended to test this hypothesis as well, but our pressure manipulations failed to significantly increase perceived anxiety among the participants. Possibly participants were very much knowledgeable about their penalty skills compared to teammates, because football teams often have pre-established penalty takers. Future work must therefore reassess this hypothesis, including the search for more effective pressure-inducing techniques.

[8] An anonymous reviewer pointed out that the two groups might also differ in the perceived importance of the accuracy demands of the task. In contrast to the high saliency group, the low saliency group had to become more accurate as practice progressed, resulting in the perception that accuracy-demands are *always* important and increasingly so.

The low sample size limits the strength of evidence of the present study (Button et al. 2013, Lohse, Buchanan & Miller, 2016; Schweizer & Furley, 2016). Recruiting a sufficient number of high-skilled football players for penalty kick studies is typically very difficult. The group of potential participants is relatively small, the commitment required is high (for this study 5-6 hours), and most football players and coaches are strongly inclined to think that penalty taking is a lottery and cannot be practiced meaningfully (Jordet et al. 2007). This is probably one of the reasons that most experimental studies examining high skilled football players have relatively low number of participants (e.g., Steenbergen & van der Kamp, 2008; Wood & Wilson, 2011; Carr et al., 2013). Nonetheless, given the small sample size the present study must be considered as exploratory, and warrants replication with a larger number of participants to increase the strength of evidence.

4.2 Practical implications and conclusions

The results are in line with previous suggestions that decision-making can increase the load on cognitive resources such as working memory (Furley & Memmert, 2010; 2012). This increased load can lead to degradation in motor performance. With respect to penalty taking, this implies that a strategy would be preferred that minimizes the load on cognitive resources. In this respect words, a goalkeeper-independent strategy may be preferred over a goalkeeper-dependent strategy –at least without further practice. However, observations from internationally competitions show equal success rates for the two strategies (Noël et al., 2015). Hence, if the player chooses to employ the goalkeeper-dependent strategy (also because it almost impossible to fully ignore the goalkeeper, see Navarro et al., 2013), then she is perhaps best advised to use implicit practice methods to improve penalty-kicking skill. This can be achieved by gradually increasing difficulty, for instance, by initially kicking from shorter distances than the official 11 meters, and/or by using relatively large targets (e.g., Savelsbergh, Canal-Bruland & van der Kamp). In fact, such an approach may also be advisable for training the goalkeeper-independent strategy, so as to minimize the changes of break down under pressure during competition.

In sum, the current study indicates that practicing implicitly may promote performance on sport-specific dual-task, such as, the performance of penalty takers who adopt a goalkeeper-dependent strategy and have to decide –based on the opponent goalkeeper's action- to which side to shoot while they are performing the run-up and the kick. Further studies must assess the benefits this conveys for performing under pressure or for players adopting a goalkeeper-independent strategy, which requires fewer cognitive resources.

References

Abernethy, B. (1988) Dual-task methodology and motor skills research: Some applications and methodological constraints. *Journal of Human Movement Studies*, 14 3: 101-132.

Armatas, V., Yiannakos, A., Papadopoulou, S., & Galazoulas, C. (2007, October). Analysis of the set-plays in the 18th football World Cup in Germany [online]. *Physical training*. Retrieved from http://ejmas.com/pt/2007pt/ptart_galazoulas_0710.html

Beilock, S L. Wierenga, S. A. &. Carr T. H. (2002) Expertise, attention, and memory in sensorimotor skill execution: Impact of novel task constraints on dual-task performance and episodic memory. *The Quarterly Journal of Experimental Psychology*, 55, 4, http://dx.doi.org/10.1080/02724980244000170

Bowtell, M., King, M. & Pain, M. (2009). Analysis of the keeper-dependent strategy in the soccer penalty kick. *International Journal of Sports Science and Engineering,* 3, 93-102.

Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J. & Munafo, M. R. (2013). Power failure: why small sample size undermines the reliability of neuroscience. Nature Reviews Neuroscience 14, 365-376.

Carr, B. M., Etnier, J. L. & Fisher, K. M. (2013). Examining the time course of attention in a soccer kick using a dual task paradigm. *Human Movement Science,* 32, 240-248.

Furley, P. A., & Memmert, D. (2010). The role of working memory in sport. International *Review of Sport and Exercise Psychology*, 3(2), 171–194. https://doi.org/10.1080/1750984X.2010.526238

Furley, P. A., & Memmert, D. (2012). Working Memory Capacity as Controlled Attention in Tactical Decision Making. *Journal of Sport and Exercise Psychology*, 34(3), 322–344. https://doi.org/10.1123/jsep.34.3.322

Jordet, G., Hartman, E., Visscher, C., & Lemmink, K. A. P. M. (2007). Kicks from the penalty mark in soccer: The roles of stress, skill, and fatigue for kick outcomes. *Journal of Sports Sciences*, 25, 121–129. http://doi.org/10.1080/02640410600624020

Krane, V. (1994). The Mental Readiness Form as a Measure of Competitive State Anxiety. *The Sport Psychologist*, 8, 189–202.

Lam, W. K., Maxwell, J. P. & Masters, R. S. W. (2009) Analogy versus explicit learning of a modified basketball shooting task: Performance and kinematic outcomes. *Journal of Sports Sciences*, 27, 179-191.

Lam, W. K., Maxwell, J. P. & Masters, R. S. W. (2010). Probing the allocation of attention in implicit (motor) learning. *Journal of Sports Science*, 28, 1543-1554.

Lee, T. D., & Magill, R. A. (1983). The locus of contextual interference in motor-skill acquisition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 9, 730–746.

Lee, T. D., Wulf, G. & Schmidt, R. A. (1992) Contextual Interference in Motor Learning: Dissociated Effects Due to the Nature of Task Variations. *The Quarterly Journal of Experimental Psychology*, 44, 4, 627-644.

Lohse, K., Buchanan, T., & Miller, M. (2016). Underpowered and Overworked: Problems With Data Analysis in Motor Learning Studies. *Journal of Motor Learning and Development*, 4(1), 37–58. http://doi.org/10.1123/jmld.2015-0010

MacMahon, K. M. A., & Masters, R. S. W. (2002). The effects of secondary tasks on implicit motor skill performance. *International Journal of Sport Psychology*, 33, 307–324.

Mann, D. T. Y., Williams, M., Ward, P. & Janelle, C. M. (2007) Perceptual-Cognitive Expertise in Sport: A Meta-Analysis. *Journal of Sport & Exercise Psychology*, 29, 457-4.

Masters, R. S. W. (1992), Knowledge, knerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *British*

Journal of Psychology, 83: 343–358. doi:10.1111/j.2044-8295.1992.tb02446.x

Masters, R. S. W., & Maxwell, J. P. (2004). *Implicit motor learning, reinvestment and movement disruption: What you don't know won't hurt you.* In A. M. Williams & N. J. Hodges (Eds.), Skill acquisition in sport (pp. 207–228). New York: Routledge

Masters, R., & Maxwell, J. (2008). The theory of reinvestment. *International Review of Sport and Exercise Psychology*. 1, 160–183.

Masters, R. S. W., Poolton, J. M., Maxwell, J. P. & Raab, M. (2008). Implicit Motor Learning and Complex Decision Making in Time-Constrained Environments. *Journal of Motor Behavior*, 40, 71–79

Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2000). From novice to no know-how: A longitudinal study of implicit motor learning. *Journal of Sports Science*, 18, 111-120.

Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2003). The role of working memory in motor learning and performance. *Consciousness and Cognition*, 12, 376–402.

Maxwell, J. P., Masters, R. S. W., Keer, E. & Weedom, E. K. (2001). The implicit benefit of learning without errors. *The Quarterly Journal of Experimental Psychology*, 54, 1049-1068.

Morya, E., Bigatão, H., Lees, A., & Ranvaud, R. (2003). Evolving penalty kick strategies: World cup and club matches 2000-2002. In T. Reilly, J. Cabri, & D. Araújo (Eds.), Science and Football V (pp. 237–242). London: Routledge.

Morya, E., Ranvaud, R., & Pinheiro, W. M. (2003). Dynamics of visual feedback in a laboratory simulation of a penalty kick. *Journal of Sports Sciences*, 21(2), 87–95. http://doi.org/10.1080/0264041031000070840

Navarro, M., van der Kamp, J., Ranvaud, R., & Savelsbergh, G. J. P. (2013). The mere presence of a goalkeeper affects the accuracy of penalty kicks. *Journal of Sports Sciences*, 31(9), 921–929. http://doi.org/10.1080/02640414.2012.762602

Noël, B., Furley, P., van der Kamp, J., Dicks, M. & Memmert, D. (2015). The development of a method for identifying penalty kick strategies in association football. *Journal of Sports Science*, 33, 1–10. http://doi.org/10.1080/02640414.2014.926383

Poolton, J.M., Masters, R. S. W. & Maxwell, J. P. (2005). The relationship between initial errorless learning conditions and subsequent performance. *Human Movement Science*, 24, 362-378.

Raab, M., Masters, R. S. W. & Maxwell, J. P. (2005). Improving the 'how' and 'what' decisions of elite table tennis players, *Human Movement Science*, 24, 326-344. http://doi.org/10.1016/j.humov.2005.06.004.

Ripoll, H., Kerlirzin, Y., Stein, J.F., & Reine, B. (1995). Analysis of information processing, decision-making, and visual search strategies in complex problem solving sport situations. *Human Movement Science*, 14, 325-349.

Savelsbergh, G., Cañal-Bruland, R., & van der Kamp, J. (2012). Error Reduction during Practice: A Novel Method for Learning to Kick Free-Kicks in Soccer. *International Journal of Sports Science & Coaching*, 7(1), 47–56. https://doi.org/10.1260/1747-9541.7.1.47

Schweizer, G., & Furley, P. (2016). Reproducible research in sport and exercise psychology: The role of sample sizes. *Psychology of Sport and Exercise*, 23, 114-122.

Sibley, B. A., & Etnier, J. L. (2004). Time course of attention and decision making during a volleyball set. *Research Quarterly for Exercise and Sport*, 75, 102–106.

Shea, J. B., & Morgan, R. L. (1979). Contextual interference effects on the acquisition, retention, and transfer of a motor skill. *Journal of Experimental Psychology: Human Learning and Memory*, 5, 179–187.

Steenbergen, B., & van der Kamp, J. (2008). Attentional processes in dribbling performance of high-skilled soccer players with congenital hemiparesis: Differences related to the side of the hemisperic lesion. *Motor Control*, 11, 55-66.

Van der Kamp, J. (2006). A field simulation study of the effectiveness of penalty kick strategies in soccer: Late alterations of kick direction increase errors and reduce accuracy. Journal of Sports Science, 24, 467-477.

Van der Kamp, J. (2011). Exploring the merits of perceptual anticipation in the soccer penalty kick. Motor Control, 15, 342–358.

Zhu, F.F., Maxwell, J.P., Hu, Y., Zhang, Z.G., Lam, W.K., Poolton, J.M. & Masters, R.S.W. (2010). EEG activity during the verbal-cognitive stage of motor skill acquisition. *Biological Psychology*, 84, 221-227.

Wilson, M. R, Wood, G. & Vine, S. J. (2009) Anxiety, Attentional Control, and Performance Impairment in Penalty Kicks. *Journal of Sport and Exercise Psychology*, 31, 761 – 775.

Wood, G., & Wilson, M. R. (2011). Quiet-eye training for soccer penalty kicks. *Cognitive Processing*, 12(3), 257–266.

Table 1. Mean (and Standard Deviations) of Performance during First Six Practice Trials with Large Target and All Practice Trials for the LS-Group and HS-Group. Note that lower values for accuracy indicate better performance (i.e. closer to the centre of the target).

	LS group	HS group
First six practice with large target		
Percentage of goalmouth hits	83 (5)	83 (5)
Percentage of target hits	50 (17)	50 (33)
Accuracy (cm)	113 (41)	117 (43)
All practice trials		
Percentage of target hits	37 (7)	27 (6)

Figure 1. Mean of percentages of targets hits for the LS-Group and HS-Group in practice sessions 1, 2 and 3.

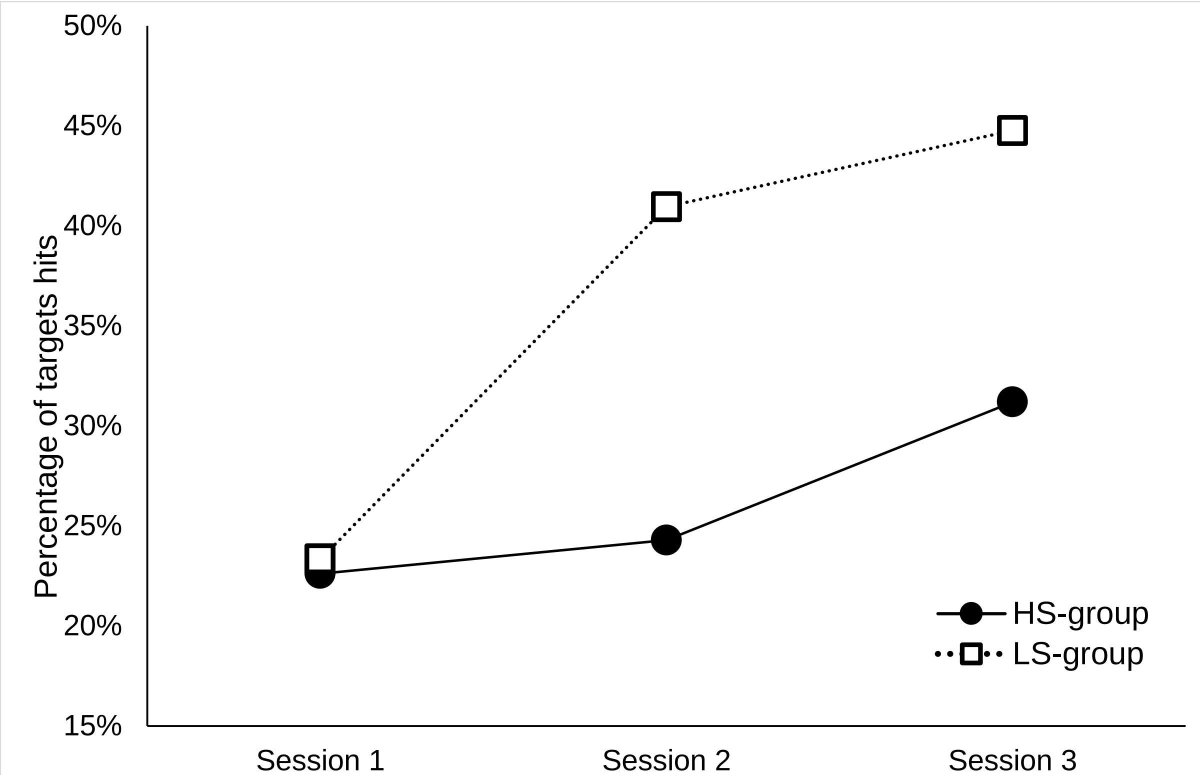

Table 2. Means (and Standard Deviations) for Performance Measures and Decision-making for the LS-Group and HS-Group as a Function of Time. Note that lower values for accuracy indicates better performance (i.e. closer to the centre of the target).

	LS-group			HS-group		
	Early	Middle	Late	Early	Middle	Late
Percentage of goalmouth hits	80 (17)	70 (17)	80 (9)	74 (13)	72 (9)	72 (9)
Percentage of target hits*	2 (2)	2 (1)	2 (2)	1 (2)	1 (1)	1 (1)
Accuracy (cm)	75 (23)	92 (27.2)	90 (12)	109 (24)	99 (20)	98 (21)
Percentage of kicks to correct side	98 (1)	70 (5)	57 (4)	94 (2)	78 (2)	56 (5)

* *It must be noted that target sizes during practice and tests were not identical, therefore lower values for target hits in post-test compared to pre-test were found.*