Neurocognitive functioning in talented soccer players

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Chapter 6

Explicit and implicit motor learning in youth elite and amateur soccer players

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Abstract

Purpose Neurocognitive functions such as inhibition and attentional skills may underlie success in sports and distinguish between elite and non-elite players. An ability that has not been studied in relation to excellent sports performance is whether elite athletes exceed in sequential motor learning. The current study investigated implicit and explicit motor learning in elite and non-elite youth soccer players.

Method Twenty-seven youth elite soccer players, and twenty-five non-elite soccer players (aged 10-12) performed a serial reaction time task (SRTT). One of the sequences must be learned explicitly, the other was implicitly learned.

Results No main effect of group was found for implicit and explicit learning on mean reaction time (MRT) and accuracy. However, an interaction was found between sequence, learning phase and group. Analyses showed no group effects for the explicit motor sequence, but youth elite soccer players showed superior speed of learning in the implicit sequence. This resulted in earlier stability and approaching an asymptote in MRT during execution of the implicit motor sequence.

Conclusions Present findings may be important for talent identification in sports because children with superior implicit learning abilities may be able to learn more (durable) motor skills in a shorter time period as compared to other children.

INTRODUCTION

A main goal of many organizations is to create an environment for young sport talents to optimally develop their performance in a specific sport by providing high level training and coaches, and adapted school programs (Baker, Horton, Robertson-Wilson, & Wall, 2003). This environment is essential for success in sports and is accompanied by high costs and efforts (e.g. Reilly, Williams, & Franks, 2000; Abbott & Collins, 2002; Van Hilvoorde, Elling, & Stokvis, 2010). Therefore, effective talent identification is a major challenge for national Olympic associations, youth academies, coaches and funding (Abott & Collins, 2004).

Ample evidence exists on the roles of both genetic factors and training in determining performance of elite athletes and distinguishing elite athletes from less well-performing athletes (Tucker & Collins, 2012). Recent studies focused on neurocognitive performance of athletes in order to investigate whether years of training or innate inter-individual differences in neurocognitive functioning are associated with superior sports performance (see for a review Yarrow, Brown, & Krakauer, 2009). For example, studies report on superior abilities of elite athletes on sport-specific perceptual abilities, visual skills (Savelsbergh, Van der Kamp, Williams, & Ward, 2005) and attention (Mann, Williams, Ward, & Janelle, 2007). Furthermore, it is shown that elite athletes outperform non-elite athletes on non-sport specific neurocognitive functions such as inhibition (Vestberg, Gustafson, Maurex, Ingvar, & Petrovi, 2012; Alves et al., 2013; Verburgh, Scherder, Van Lange, & Oosterlaan, 2014). Another important neurocognitive function in sports is the ability to acquire complex movements: Obtaining new motor skills is important for performance in sports, and these motor skills are acquired through repeated practice (Yarrow et al., 2009; Doyon & Benali, 2005). In 1993, Ericsson and colleagues proposed the theory of “deliberate practice”, which is described as intensive practicing and repeating of motor skills (Ericsson, Krampe, & Tesch-Römer, 1993). Studies have shown that learning movements follow a pattern of stages in which a phase of fast learning is followed by a phase of consolidation, which is completed by a phase of optimization of the movements in terms of precision and timing. This final stage is also called the automatization phase and requires less attention compared to earlier learning stages (Brashers-Krug, Shadmehr & Bizzi, 1996; Penhune & Steel, 2012).

These phases of learning, consolidation, and automatization are strongly linked to different conceptualizations of learning. In particular, skill acquisition can be reached by explicit or implicit learning. Explicit learning is the learning of new skills using explicit instructions and rules, resulting in declarative knowledge and the ability to articulate how to perform the skill (Liao & Masters, 2001). In contrast, implicit learning is learning unconsciously, without instruction and rules, leading to few declarative knowledge (Reber, 1989; Rendell, Farrow, Masters, & Plummer, 2011).

Implicit learning has several advantages over explicit learning (Reber, 1993). First, execution of implicitly learned motor skills is more stable in terms of intra-individual variability than explicitly learned skills (Poolton, Masters, & Maxwell, 2007; Gabbett & Masters, 2011). Second, it is not related to the intelligence of the learner (Maybery et al., 1995). Third, a study by Liao and Masters (2001) showed that elite table tennis players who learned a new skill implicitly, performed better than a group that explicitly learned a skill when a secondary task was added. Fourth, implicitly obtained skills are less vulnerable to choking under pressure (Masters, Poolton, & Maxwell, 2008; Lam, Maxwell, & Masters, 2009). Choking under pressure is a well-known phenomenon in sports, which describes a decrease in performance with increasing stress put on an athlete (Hill, Hanton, Matthews, & Fleming, 2010). Because implicitly learned motor skills do not depend on declarative knowledge and an athlete cannot “think” about execution of the skills, performance of implicitly learned skills is less likely to decrease in time-constrained situations as compared to explicitly learned skills (Masters et al., 2008; Lam et al., 2009). However, in some situations explicit learning may be advantageous, for instance when declarative knowledge is required for transfer of knowledge to new skills or in teaching (Sun, Merrill, & Peterson, 2001).

Concerning research on the development of explicit and implicit motor learning, numerous studies have been performed in healthy children (Meulemans, Van der Linden, & Perruchet, 1998; Thomas & Nelson, 2001; Savion-Lemieux, Bailey, & Penhune, 2009). However, very little is known about skill acquisition and motor learning in young talented athletes. This is surprising because knowledge about learning systems in talented youth may provide valuable information for coaching (Gabbett & Masters, 2011). Moreover, the ability of fast and accurate motor learning is important for talents because it enables the young athlete to learn specific skills at a young age and reach a higher level of performance earlier than his or her peers. Individual differences in the efficiency of motor learning might be promising predictors for future levels of performance. To the best of our knowledge, the present study is the first to address sequential explicit and implicit motor learning in youth talented athletes by comparing youth elite soccer players (playing at a Premier League soccer club's youth academy) to non-elite soccer players (playing at a regular amateur soccer club). Explicit and implicit motor learning will be measured using the serial reaction time task (SRTT), which is developed in by Nissen and Bullemer (1987) to investigate the influence of adding a secondary task on learning. On a SRTT, participants are required to learn a sequence of stimuli, which should be automatized after intensive practice of the sequence (for a review, see Robertson, 2007). The SRTT has been shown to be a valid instrument for measuring motor learning in a broad range of age-groups, healthy populations, and clinical populations such as attention-hyperactivity deficit patients, Parkinsons disease, Alzheimers disease and dyslexia (Vicari, Marotta, Menghini, Molinari, & Petrosini, 2003; De Kleine & Verwey, 2009; Barnes, Howard, Howard, Kenealy, & Vaidya et al., 2010; Van Tilborg and Hulstein, 2010). Because both groups of soccer players in the present study are not familiar with learning skills with their hands, the elite soccer group could not benefit from experience in terms of soccer training or expertise on this task and results may therefore provide new insights about a possible underlying capacity that facilitates highly talented athletes in learning new motor skills. As has been shown in studies of Willingham & Goedert-Eschmann (2002) and Song, Marks, Howard, & Howard (2009), explicit and implicit motor learning will be investigated parallel in the present study in order to investigate whether youth elite soccer players faster learn explicit or implicit motor sequences as compared to non-elite youth players.

METHODS

PARTICIPANTS

Fifty-two soccer players participated in the present study. Twenty-seven elite soccer players (mean age 12.3 years, SD 0.63, all male) were recruited from two youth academies of a Dutch Premier League soccer club. Twenty-five participants played at an amateur soccer club in Amsterdam (mean age 11.5

years, SD 1.2, 9 females) and were recruited from teams in the same age-category as the elite soccer players. The elite soccer players all played in the highest competition level for their age, and on average four levels higher than the amateur soccer players (see for more details on the Dutch soccer system Verburgh et al., 2014). Participants were free of known behavioural, learning and medical conditions that might impact performance on the motor learning task and were excluded when they had an IQ <70, measured by a short form of the Wechsler Intelligence Scale for Children III (Wechsler, 1997). Demographics of both groups are displayed in table 1.

MATERIALS

SERIAL REACTION TIME TEST (SRTT)

A modified version of the SRTT (Robertson, 2007) was used to measure explicit and implicit motor learning in parallel. Four squares were horizontally presented on a computer screen with a black background (figure 1). The squares were 2.5 x 2.5 cm and corresponded to keys on the keyboard. The most left square corresponded to the V key, the second square to the B key, the third to the N key, and the most right square to the M key. The participants were required to lay the fingers of their dominant hand on top of the keys (with the index finger on the V etc., or the little finger on the V for left-handed participants).

The sequence that participants were required to learn explicitly consisted of a sequence of targets with a fuchsia border that filled in solid fuchsia in the following order: MBVNBMNV. The implicit sequence consisted of targets with a yellow border that filled in solid yellow. The reversed order (VNMBNVBM) of the explicit sequence was used in order to control for complexity of the sequence. A sequence started with a 500 ms interval after one of the squares filled in solid fuchsia or yellow to which the participant was required to respond as fast as possible by pressing the corresponding key on the keyboard. The task started with one block of 10 practice trials with a standardized sequence of four fuchsia squares: VBNM. With this simplified example of the explicit sequence, participants were instructed about seeing and learning an order of fuchsia (explicit) stimuli in an explicit way. Following the practice trials, participants were instructed to learn the eight targets of the fuchsia sequence (like in the practice trials). Nothing was told about yellow stimuli. Five test blocks were administered, each containing 25 explicit and 25 implicit sequences presented in a randomized order, but identical for each participant. In total, both sequences were performed 125 times by a participant. All four target squares remained on the screen during a trial. The target square remained filled in fuchsia or yellow until the participant responded correctly. The inter-stimulus interval was 120 ms, the inter-trial interval 500 ms, and there was a short break between blocks. At the end of each block, the participants received feedback about their mean reaction time and accuracy of the preceding block. The mean reaction time (MRT) and accuracy of each test block and of both sequences were used as dependent variables.

RECALL AND RECOGNITION QUESTIONNAIRE

After completion of the SRTT, participants immediately filled in a short questionnaire about the task that first asked them to recall the explicit sequence and then to identify the explicit sequence from a four-choice question (recognition test). Next, it was asked if the participant had anything to report about the yellow stimuli and if the participant said that he or she suspected a sequence in the yellow stimuli, the recall and recognition questions were examined for the implicit sequence as well. Aim of the questionnaire was to ensure that participants indeed gained declarative knowledge of the explicit sequence, but not of the implicit sequence.

PLAYING A MUSIC INSTRUMENT, GAMING AND COMPUTER TIME

Because some evidence suggest an association between playing a music instrument and motor skills (Romano-Bergstrom, Howard, & Howard, 2012), we asked whether participants played an instrument and if so, which and instrument they play, and since when, and if the participant attended lessons. Also, because an association was found between gaming and motor skills (Barnett, Hinkley, Okely, Hesketh, & Salmon, 2010; Rosenthal et al, 2012; Hammond, Jones, Hill, Green, & Male, 2014) we also assessed gaming and computer time (minutes per week) by self-report questionnaire (TNO, 2007). Participants were required to indicate how many days per week and how many minutes per day they participated in the activities listed (e.g., ‘How many days a week do you use the computer’? ‘How many times do you play games on a game console’?). Total minutes per week spent on gaming (game console such as Nintendo® or PlayStation®) and total minutes per week spent on the computer (personal computer, laptop or tablet) were included as dependent measures.

FULL-SCALE IQ ESTIMATION

Full-scale IQ was estimated by the Wechsler Intelligence Scale for Children III (Wechsler, 1997). Two subtests (Vocabulary and Block Design) were administered, which each correlate > .90 with full-scale IQ (Groth-Marnat, 1997).

PROCEDURE

The study was approved by the local ethical committee of the Institutional Review Board of the VU University Amsterdam. All participants and parents and/or legal guardians were informed about the procedures of the study before giving their written informed consent prior to participation. The elite youth soccer players performed the test in a quiet room at their soccer academy, prior to their soccer training. Non-elite soccer players were tested in a quiet room at the VU University Amsterdam, also prior to training hours. First, Full-scale IQ was estimated by the Wechsler Intelligence Scale for Children III. Next, the Serial Reaction Time task was administered, following by the questionnaire examining awareness of the learned motor sequences.

STATISTICAL ANALYSES

SPSS version 22.0 was used for all statistical analyses. A total of nine participants (five elite soccer players, three non-elite soccer players) were excluded from further analyses due to trying to influence task performance by switching fingers on the keyboard or making more than 20% errors, suggesting poor compliance with the task instructions.

Possible group differences in age, IQ, gaming and computer time were tested using univariate analyses of variance (ANOVA) and Pearson correlations within each group were performed to determine the possible relationship between those variables and SRTT measurements.

Next, to examine the results of the task manipulation and possible group differences, mean reaction times (MRTs) and accuracy of both explicit and implicit sequences derived from the SRTT were subjected to separate two-way repeated measures ANOVA with two within-group factors: MRT or accuracy of learning phase (five levels: block 1 - 5), learning strategy (two levels: explicit and implicit) and group (two levels: elite soccer players, non-elite soccer players) as between-subject factor. Polynomial contrast analyses were performed to examine linear, quadratic, or cubic trends as previous research has shown asymptotic learning curves on the SRTT (Poldrack et al., 2005; Stickgold, 2005). Furthermore, to control for possible influences of age, IQ, gaming, computer time, gender, handedness, and playing an instrument were examined by re-running the two-way repeated measures ANOVA's with each of those possible confounders as covariate and if required, included as covariates in the final two-way repeated measures ANOVA's on MRT and accuracy and subsequent polynomial contrast analyses. Finally, the two-way repeated measures analyses were rerun without subjects who recalled the implicit sequence to control for possible effects of declarative knowledge of the implicit sequence on performance. Greenhouse-Geisser corrections were applied when the sphericity assumption of the F test was violated. Alpha was set at .05.

RESULTS

PARTICIPANTS

Group characteristics are presented in table 1. Despite all participants played in similar age-classified teams, the elite soccer players were significantly older than the non-elite players. This could be explained by the relative age effect: Athletes born closest to the cut-off age used for admittance to a particular age group are overrepresented in a talented group because they are often more matured as compared to their younger peers. This effect is commonly seen in elite sports (Hancock, Ashley, & Côté, 2013) Age was significantly related to MRTs of both the explicit and implicit sequence only for the first block (r=-.46, p<.01 and r=-.49, p<.001 for the explicit and implicit sequence, respectively), indicating that older children were faster in the first block of both sequences. Therefore, age was included as covariate in further analyses. Significant Pearson correlations were also found between IQ and the MRTs (-.26>rs<.-46, .002>ps<.05), indicating that a higher IQ is associated with faster MRTs. However, because groups did not differ on IQ, IQ was not included as covariate. Gaming and computer time were not associated with MRTs of both sequences (.03>rs<.13, .31>ps<.86).

SERIAL REACTION TIME TEST

The two-level repeated measure analysis with MRTs of both sequences as dependent variables, age as covariate, and group as between-subject factor

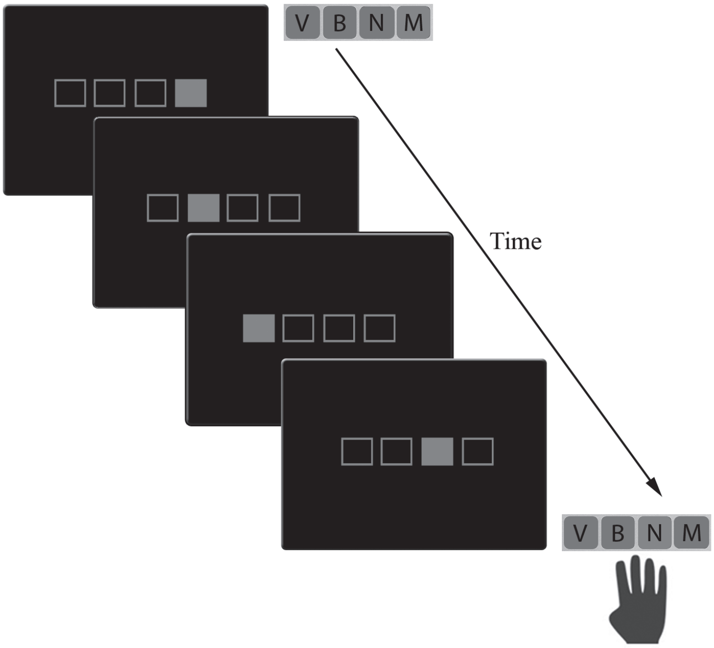

Figure 1. Schematic representation of the first four windows of the explicit sequence of the serial reaction time task (SRTT).

revealed a linear effect of sequence ($F(1,43)=5.5$, $p<.05$, partial $eta^2=.11$), indicating faster MRTs in the explicit sequence. Furthermore, a linear effect of learning phase was found, ($F(1,41)=17.5$, $p<.001$, partial $eta^2=.30$), indicating faster MRTs in later blocks. The quadratic effect of learning phase was also significant ($F(1,41)=12.1$, $p=.001$, partial $eta^2=.23$), indicating that MRTs approached an asymptote in later blocks. There was no evidence for an interaction effect between learning phase and sequence ($F(4,40)=.47$, $p=.76$), indicating that the decreases in MRT during the task were not different for the sequences. Furthermore, no significant main effect of age ($F(1,41)=.83$, $p=.37$) and no significant interaction between sequence and age ($F(1,41)=.26$, $p=.61$) were found. However, an interaction effect was found between learning phase and age ($F(1,41)=8.3$, $p<.01$, partial $eta^2=.17$). Post hoc pair wise comparisons indicated that older participants showed faster MRTs than younger participants, but only in the first block (F(1,42)=4.3, p<.05, partial eta^2=.09).

Moreover, no significant main effect of group (F(1,43)=.40, p=.53), no significant interaction between learning phase and group (F(1,41)=.55, p=.46) and no significant interaction between sequence and group were found (F(1,41)=.27, p=.61). However, a significant linear effect between learning phase, sequence and group was found (F(1,41)=5.4, p<.05, partial eta^2=.12), indicating that the interaction between learning phase and group was different for the individual sequences (figure 2).

To further investigate the three-way interaction, post hoc repeated contrast analyses were performed which showed no significant group differences or interactions between group and learning phase for the explicit motor sequence (all contrasts ps>.05). However, for the implicit motor sequence, interaction effects were found between learning phase and block 2 and 3 (F(1,40)=1.3, p<.05, partial eta^2=.13) and block 3 and 4 (F(1,40)= 4.5, p<.05, partial eta^2=.10). No significant interactions were found between learning phase and group for block 1 and 2, and 4 and 5 (F(1,40)=1.3, p=.26 and F(1,40)=.19, p=.66, respectively). This indicates that the groups started and ended at similar MRTs, but that in the third block of the implicit sequence, the MRTs of the elite soccer players already approached an asymptote, whereas the MRTs of the non-elite soccer players continued learning between the third and fourth block.

The two-level repeated measure analysis with accuracy of both sequences as dependent variables revealed no significant main effect of group and no significant interactions between group, learning phase or sequence were found on accuracy (all Fs<1.1, ps>.36). Additionally, the main effects of age and interactions involving age on accuracy were not significant (all Fs<2.5, ps>.12). Moreover, Pearson correlations showed that accuracy was not significantly related to MRT (.11>rs<-.05, .99>ps<.41), indicating that there was no speed-accuracy trade-off. The separate two-way repeated measure ANOVA's with IQ, gaming, computer time, gender, handedness, and playing an instrument as covariates showed that results remained unchanged. Finally, the results were not changed when the analyses were rerun without subjects who correctly recalled the implicit sequence (n=2 for the implicit sequence).

RECALL AND RECOGNITION QUESTIONNAIRE

Free-recall and recognition of the sequences were analysed to assess the effectiveness of the sequence manipulation. It was shown that 24.6% of the participants correctly recalled the complete explicit sequence, and 59% correctly recognized that sequence. For the implicit sequence, 64% of the participants did suspect an order in the stimuli. Only 9% of these participants who suspected an order in the stimuli correctly recalled the complete implicit sequence, indicating that only 5.9% of all participants recalled the sequence. Twenty-six percent of the 64% that suspected an order correctly recognized the sequence, which means that only 17% of all participants correctly recognized the sequence. This indicates very low awareness of the implicit sequence. There were no group differences in recall and recognition for both sequences. No difference in performance was found between participants that did or did not recall or recognize the sequences. Group results are shown table 1.

DISCUSSION

The present study investigated implicit and explicit motor learning in youth talented athletes by comparing elite soccer players and non-elite soccer players in terms of speed of motor learning using the Serial Reaction Time task (SRTT).

Results show a steep learning curve as measured by MRTs of both sequences: During the first three blocks, a rapid decrease in MRTs was found for both the explicit and implicit sequence with performance approaching asymptote performance in the last blocks. This result is in line with the learning phases described by Penhune and Steel (2012). It was shown that MRTs of the explicit sequence where somewhat faster than MRTs of the implicit sequence, which is also in line with previous literature (Curran & Keele, 1993; Maxwell, Masters, & Eves, 2000). No differences were found on accuracy for learning phase, sequence and groups. Results of the explicit motor sequence suggest that when participants were explicitly instructed on learning the sequence, both soccer player groups showed similar performance with equal learning curves with a similar decrease in reaction times during the course of the task.

Importantly, the elite soccer players learned more rapidly on the implicit sequence, reaching asymptote performance after the third block with fast and stable execution of the motor sequence, whereas the non-elite soccer players

Table 1. Demographic characteristics

	Youth Elite Soccer Players (N=22)	Non-Elite Soccer Players (N=22)	P-value
Demographics			
Age	12.3 (0.63)	11.5 (1.2)	.01[a]
Estimated full-scale IQ	100 (14.7)	105 (14.2)	.26[a]
% Right-handed	89	88	.60[b]
Uses music instrument (n)	4	5	.40[b]
Gaming (minutes/week)	171.1 (217)	184.4 (293.2)	.85[a]
Computer time (minutes/week)	495 (539.7)	490.8 (415.4)	.98[a]
Questionnaire			
Recall explicit sequence	25.9%	23.3%	.43[b]
Recognition explicit sequence	52%	66%	.10[b]
Recall implicit sequence	7.4%[c]	4.3%[c]	.70[b]
Recognition implicit sequence	23.5%[c]	10%[c]	.44[b]

Note: IQ= Estimated full-scale intelligent quotient. [a]Univariate analysis of variance, [b]Fisher's exact test, [c]Percentage correctly recalled and recognized of the participants who reported to suspect an order in the implicit sequence.

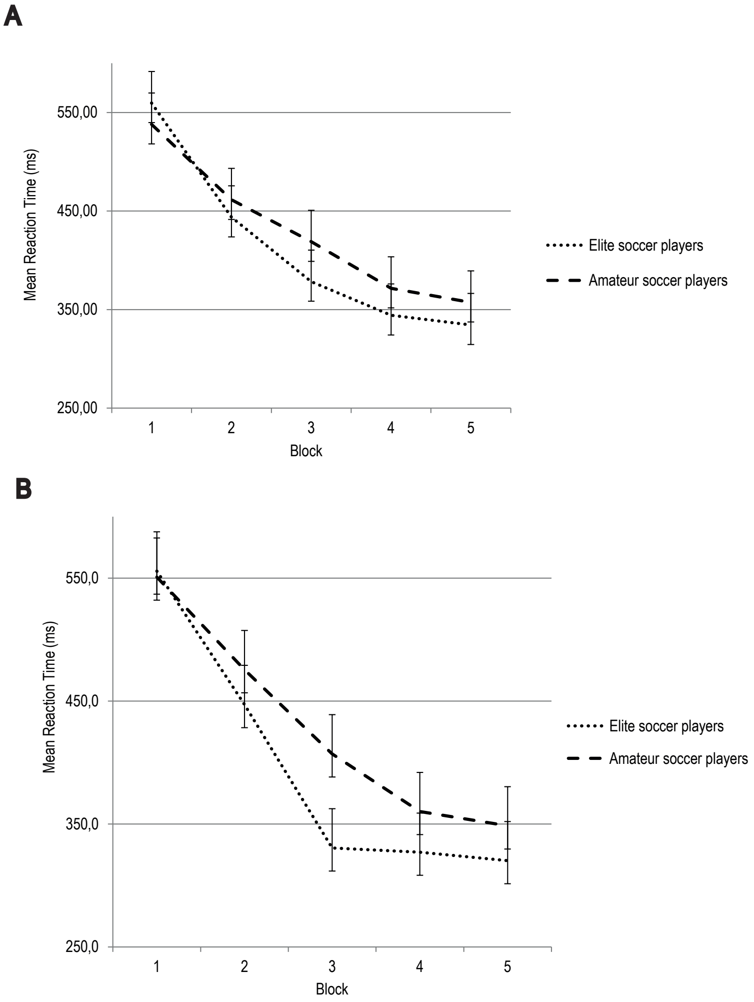

Figure 2. Learning curves for both groups. (A) Mean reaction times per block for the explicit motor sequence; (B) Mean reaction times per block for the implicit motor sequence. Vertical bars show standard errors.

continued learning during the fourth block. These results provide preliminary evidence that when nothing is told about what should be learned, or even that something should be learned, the elite soccer players learn faster than the non-elite soccer players. In other words, it may be suggested that elite soccer players are superior in the early learning phase. The rapid first stage improvement in performance is attributed to the cortico-cerebellar and cortico-striatal networks and it has been shown that the lateral cerebellum plays a crucial role in early implicit motor learning (Penhune & Doyon, 2005; Tvzi, Münte, & Krämer, 2014). Moreover, a recent study showed that white matter integrity of the dentato-thalamo-cortical tract (DTCT), connecting the lateral cerebellum to motor and prefrontal areas, is associated with motor sequence learning (Schulz et al., 2014). In addition, it has been shown that white matter integrity of these circuits predicts performance during implicit motor learning (Bennett et al.,2011), which may lead to the suggestion that youth elite soccer players have better connectivity in these circuits. Indeed, studies showed increased white matter integrity in other experts such as musicians (see for a review, Dayan & Cohen, 2011).

It may be suggested that in sports, implicitly learned skills are beneficial over explicitly learned skills because there is no time to think about the execution of specific motor skills and decreases in performance due to choking are incompatible with elite level sports performance (Hill et al., 2010). Our findings are therefore important for talent identification: when a young athlete performs well on implicit learning tasks, he or she may be able to learn more (durable) motor skills in a shorter time period of time compared to other children. Because we show preliminary evidence for superior implicit learning in young talented athletes as compared to non-elite athletes, it may be speculated that efficiency of implicit motor learning in young athletes can be a promising predictor for future elite performance. Furthermore, a practical implication of the current findings is that also in young athletes, implicit motor learning should be encouraged. Gabett and Masters (2011) described several possible effective strategies for improving implicit learning such as the use of errorless learning (learning without mistakes through step-by-step introducing of parts of a new skill), random practice (flexible working on skills, instead of a logical structure during training), or using dual-tasks to avoid step-by-step learning of a specific skill.

A limitation that should be noted is that the current study does not allow drawing conclusions about possible differences in robustness of both types of motor learning. This is an important issue because in elite sports, motor skills should be fully automatized in order to benefit performance (Beilock & Carr, 2001). Inclusion of a delayed retention task would allow examining robustness in performance of both types of motor learning (Stickgold, 2005) and an offline learning period (e.g. sleeping) could be included in order to investigate consolidation of both types of motor learning (Robertson, Pascual-Leone, & Press, 2004). Moreover, it would be interesting to translate the SRTT to gross motor skills with direct relevance for soccer to increase generalizability on achieving soccer specific motor skills.

In conclusion, the present study showed that with explicit learning instructions, youth elite soccer players did not learn faster as compared to youth non-elite soccer players, but when learning was implicit (unintentionally), elite soccer players outperformed the non-elite soccer players. Results might be relevant in view of talent development in elite sports as implicitly learned skills are more robust and are less prone to interference in stressful conditions as compared to explicitly learned skills. Future research should investigate whether individual differences in the efficiency of implicit motor learning could be predictors for future levels of performance.

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