How Should Developing Basketball Shooters Learn: Implicitly, Explicitly or Sequentially?

Mariana C. Lopes

Universidade Federal de Viçosa

Maicon R. Albuquerque

Universidade Federal de Viçosa

Markus Raab

German Sport University and London South Bank University

Authors' Note

Mariana C. Lopes and Maicon R. Albuquerque, Department of Physical Education, Universidade Federal de Viçosa. Markus Raab, Institute of Psychology, Department of Performance Psychology, German Sport University. Markus Raab also works at School of Applied Sciences, London South Bank University.

This research was supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazil) and German Academic Exchange Service (DAAD, Germany).

Correspondence concerning this article should be addressed to Mariana Calábria Lopes, Universidade Federal de Viçosa, Av. Peter Henry Rolfs, s.n., Campus Universitário, CEP 36570-900, Viçosa, Minas Gerais, Brazil.

Contact: lopesm@gmail.com

How Should Developing Basketball Shooters Learn: Implicitly, Explicitly or Sequentially?

Abstract

Purpose: The purpose of this study was to examine the effect of explicit and implicit learning in children, as well as a sequential application of learning modes, in the acquisition of the basketball shooting skill in an ecological setting. **Method**: Participants (n=80) were novices in basketball, ages 9 to 12 years old. The experimental groups followed three different methods of training, which combined technical and tactical aspects: (a) explicit practice for the development of declarative knowledge, (b) implicit practice for the development of the procedural knowledge, and (c) sequential practice (implicit first and then explicit), as well as (d) a control group, which participated only in the measurements. A pre-test and a post-test measured the performance of basketball shooting skills in isolation. A transfer test in a 3-on-3 game condition was also applied. **Results:** Results indicate that the learning groups showed the predicted implicit or explicit motor learning. All intervention groups improved in a similar manner as a consequence of practice and there was no difference between the groups in the performance of the basketball shooting skill under game condition. The sequential learning group most closely resembled the explicit learning group in performance in the transfer test and explicit knowledge acquired. **Conclusions:** The current findings indicate no disadvantage when implicit motor learning is applied in complex environments with children.

Keywords: Sport; motor learning; children; decision making

How Should Developing Basketball Shooters Learn: Implicitly, Explicitly or Sequentially?

Most sports activities in childhood, regardless of the purpose or form of practice (e.g., in sports clubs or school physical education classes), involve the performance of motor skills. For instance, in team sports like basketball, ball skills are assumed to be complex motor skills because they are generally practiced in a dynamic sports setting (Houwen, Visscher, Hartman, & Lemmink, 2007), which demands fast and effective decisions (Weigel, Raab, & Wollny, 2015). Thus, for children, it is important to develop both motor and cognitive skills. Although this statement is widely accepted, the trend has been for research to deal separately with motor and cognitive learning in sports (but see Raab, Lobinger, Hoffmann, Pizzera, & Laborde, 2016).

How motor and cognitive skills are acquired on the route to expertise has quite often been examined via cross-sectional studies, ignoring the processes involved when children and adolescents achieve changes in decision-making performance (Marasso, Laborde, Bardaglio, & Raab, 2014) and motor skill (Masters, Van der Kamp, & Capio, 2013). A developmental perspective is very important in the sports context to provide a new meaningful way to understand athlete behavior which takes into account the influence of maturation and learning, and provides answers to questions on how learning is best organized for developing athletes (Marasso et al., 2014), such as the one posed in the title of this paper.

In regard to motor learning, a child can learn sports skills as a weekend player or a high-level athlete, which are very different things (Masters, 2013). For the athlete, skill learning is almost always done explicitly, through testing of hypotheses and trainers' instructions, to establish the best way to reach the expected level of performance. When children play one-on-one basketball, for fun, in a driveway for some hours, the implicit learning may be more likely to occur (Côté, Murphy-Mills, & Abernethy, 2012)., i.e., the child does not even intend to learn and cannot verbalize how to perform the learned movement.

This distinction shows that motor learning can be supported by two cognitive pathways that operate in parallel: an explicit path and an implicit path (Masters & Maxwell, 2004). Recently in a consensus paper, Kleynen et al. (2014) defined explicit learning as "*learning which generates verbal knowledge of movement performance (e.g., facts and rules), involves cognitive stages within the learning process and is dependent on working memory involvement*." Explicit learning includes, for instance, verbal information from a coach and multiple instances of feedback and guidance on how the movement should be done. In contrast, implicit learning involves unintentional and automatic acquisition of knowledge (Frensch, 1998). This resulting association is stored as complex and procedural knowledge (Masters & Maxwell, 2004), with little or no increase in verbal knowledge of movement performance (Kleynen et al., 2014).

In recent years, several paradigms for implicit motor learning have been proposed, but most are difficult to maintain over the extended periods of practice necessary for expert performance (Masters, 2013). One paradigm developed to promote implicit motor learning that has evidence of generalization to children is errorless learning (Capio, Poolton, Sit, Eguia, & Masters, 2013; Capio, Poolton, Sit, Holmstrom, & Masters, 2013). The paradigm constrains the environment so that errors committed during practice are reduced, particularly in the early stages of learning (Maxwell, Masters, Kerr, & Weedon, 2001). This may result in better performance and may well have a significant influence on psychological attributes that shape child motor development, such as motivation and perceived competence (Masters et al., 2013). Therefore, the "errorless" (Masters, 2013) method was preferred to promote implicit motor learning, rather than analogy learning ("cookie jar analogy") used on previous work (Lam, Maxwell, & Masters, 2009). Moreover, the main focus of the “cookie jar analogy” is the movement of the arms and the hands, while leg movements are not emphasized. As we offered instruction in the explicit group about the whole body movement, this analogy seems insufficient.

Research on motor learning demonstrates that implicit learning, in contrast to explicit learning, is more stable under conditions of psychological stress (Koedijker, Oudejans, & Beek, 2008; Liao & Masters, 2001), cognitive load (e.g., decision making; Masters, Poolton, Maxwell, & Raab, 2008; Poolton, Masters, & Maxwell, 2006; Tielemann, 2008); and physiological fatigue (e.g., maximum effort; Masters, Poolton, & Maxwell, 2008; Poolton, Masters, & Maxwell, 2008). Moreover, in implicit learning the movement rules are difficult to verbalize (Masters & Maxwell, 2004). Conversely, explicit learning is less resistant to external influences and errors, the movement is easily described, and its execution depends on working memory (Masters & Maxwell, 2004).

As argued above, most previous studies focused on either motor learning or cognitive learning. Among those cited above, Tielemann´s (2008) work stands out. This study was designed to analyze the effects of implicit and explicit learning in the acquisition of skills when the teaching process involves motor and tactical aspects at the same time. Tielemann (after marriage, Schlapkohl) tested predictions of early integration of implicit and explicit motor and cognitive skill learning of performance and movement patterns using instruction manipulations (Schlapkohl, Hohmann, & Raab, 2012). The study investigated the learning of the topspin forehand shot in table tennis. The implicit group adopted the paradigm of "analogy learning" and the explicit group was instructed with the "step-by-step" method of teaching movement rules. The results revealed that the implicit group both performed better at the end of the learning phase and had a more stable performance when a decision-making task was added compared to the explicit group. A post-test revealed, however, that the explicit group obtained higher declarative knowledge of the technical skill in question.

In the sports context, technical and tactical training usually occur in conjunction, yet in most research involving motor learning in sports, the technical and tactical aspects have been treated separately in order to reduce the complexity of the learning situation. In the present study, the effects of implicit and explicit learning in the acquisition of the basketball shooting skill will be investigated with an integrated training (technical and tactical), in order to increase the ecological validity of the approach. Most studies of implicit and explicit motor learning have been performed in a laboratory (Kleynen et al., 2015), which allows great control over the variables involved, but does not necessarily transfer to real situations (but see Capio, Poolton, Sit, Eguia, et al., 2013; Capio, Poolton, Sit, Holmstrom, et al., 2013), especially in team sports, which have a very dynamic context (Marasso et al., 2014).

Although the two pathways to learning (implicit and explicit) can occur separately, they can also take place in combination or sequentially (sequential or hybrid learning). Poolton, Masters, and Maxwell (2005), for example, investigated sequential motor learning (first implicit, then explicit), comparing a sequential group with an explicit learning group in a golf putting task. The results showed that the two groups had similar performance during and after the learning phase, and there was no significant difference in the number of verbalized movement rules. However, in a transfer test, in which participants had to perform motor skills with a secondary task that involved counting tones, the sequential group maintained its performance, but the explicit group's performance declined. Brief initial periods of implicit motor learning during the early stages of learning seem to have provided learners with the advantage of stability under pressure or dual tasking, even after an explicit instruction presentation about the movement. This finding has practical relevance, given that it is impossible to restrict a learner to an entirely implicit learning environment (Masters, 2013).

Furthermore, it is important to note that the majority of the studies cited above (Masters, 2000; Masters, Poolton, & Maxwell, 2008; Masters, Poolton, Maxwell, et al., 2008; Tielemann, 2008) and most of the work on implicit motor learning have been conducted with adults. If a major goal of motor learning research is to support the practice in physical education classes and sport settings involving children and adolescents, it is precipitate to generalize the findings from adult populations (Perreault & French, 2015). Some few exceptions are the studies from Capio and colleagues (Capio, Poolton, Sit, Eguia, et al., 2013; Capio, Poolton, Sit, Holmstrom, et al., 2013). They conducted two studies to investigate the use of errorless paradigm to teach the fundamental movement skill of throwing to children either with or without intellectual disabilities. The findings of both studies support the use of the errorless paradigm to promote the learning of throwing and it seems particularly beneficial for low-ability children. Although these studies were done with children, they investigated a fundamental skill and not a sport specific skill. So, it is not yet clear how well these findings generalize to the sport context.

Given that findings regarding complex movements and sports in children are lacking, we thought to first test the generalization of implicit and explicit learning. We based the following hypotheses on the integration of effects of different learning types to promote generalization to developing basketball shooters: (a) an implicit group and a sequential group will demonstrate higher performance of basketball shooting after an intervention phase compared with an explicit group and a control group (Tielemann, 2008); (b) when the technical skill of shooting a basketball has to be performed simultaneously with a decision-making task, the performance of the implicit and sequential groups will remain stable, whereas the performance of the explicit group and the control group will be reduced (Masters, Poolton, Maxwell, et al., 2008; Poolton et al., 2006; Tielemann, 2008); (c) the explicit and sequential groups will be able to verbalize a larger number of movement rules regarding shooting a basketball after the intervention in comparison to the implicit and control groups (Masters & Poolton, 2012).

At a more exploratory level, from the developmental perspective, we examined whether implicit and explicit motor learning replicate effects found earlier in adults or in the fundamental movement skill of throwing, with the aim of providing a way to orient coaches' and teachers' training choices during child development.

Method

Sample

A total of 80 participants (25 girls and 55 boys; 9–12 years old; M_{age} = 10.61 years, SD = 0.85) took part voluntarily in this study. The participants were assigned to one of three experimental groups (implicit group: n = 18, explicit group: n = 20; sequential group: n = 19) or a control group (n = 23).

All participants were novices in basketball and had no previous experience outside physical education classes at school. They were recruited through notice boards and flyers distributed at schools and sports clubs in Germany. Parents agreed to their children participating by signing an informed consent, which contained information about the objectives and the anonymous character of the research and that they could withdraw any time. The study was approved by the Institutional Review Board at the University of Heidelberg.

Measures

Participants each completed three tests designed to measure the effect of the learning procedure on (a) basketball shooting, (b) basketball shooting under game conditions, and (c) declarative knowledge. In test conditions b and c, two independent raters (C-license basketball trainers in Germany) who were blind to the experimental conditions under which each participant performed rated participant performance. All skill tests were performed on a court with official baskets and dimensions according to the rules of the International Basketball Federation. The balls were smaller and lighter than for adults (Molten N. 5).

Basketball shooting test. In the shooting test, participants were required to throw the ball in the basket from a distance of 2.80 m from the projected line of the backboard (distance recommended for the free throw for this age – Showalter (2007)). Participants performed two blocks of 10 trials and shooting performance was assessed using a 6-point scale developed by Hardy and Parfitt (1991): 5 was awarded for a ‘‘clean’’ basket (i.e., ‘‘swish’’); 4 for rim and in; 3 for backboard and in; 2 for rim and out; 1 for backboard and out; and 0 for a complete miss. The maximal score was 50 points per block. To prevent excessive physical stress in the participants, blocks were separated by an interval of at least 1 min. All participants were allowed to perform two practice trials in the pre-test and post-test phases. Only the best block of each test phase was used for analysis to reduce the intra-individual variance.

Basketball shooting test under game conditions. In this test situation, the participants were embedded in a game, which can directly trigger tactical solutions during skill execution in an ecologically valid situation. The game was played on a basketball half-court between two teams of three players and lasted 8 min. Assessment of the performance of the basketball skills under decision-making constraints was made using the Game Performance Assessment

Instrument (GPAI), which has been previously validated in basketball (Oslin, Mitchell, & Griffin, 1998) and has several components (Mitchell, Oslin, & Griffin, 2006). In this study we used the Skill Execution Component to evaluate the performance of the shooting skill in the game, which concerns the efficient execution of selected skills. Each time the observed participant shot the ball to the basket, his action was evaluated as either "efficient" or "inefficient" by the rater in the context of the game situation. Each player starts with a score of 0 an gains 1 point per effective skill. The participants' performance in the game-test situation was recorded using a Sony digital video camera (model DCR-TRV900E) and was further analyzed by two independent raters. Intra-class correlation coefficients (ICCs) showed significant correlations between the independent raters in their scoring of skills in the pre-test (efficient skill execution, ICC = .91, $p < .001$; inefficient skill execution, ICC = .81, $p < .001$) and post-test (efficient skill execution, ICC = .92, $p < .001$; inefficient skill execution, ICC = .83, $p < .001$). After sufficient results of the inter-rater correlation, the performance indicators were calculated according to the protocol of Mitchell et al. (2006) with the changes proposed by Memmert and Harvey (2008). Mitchell et al. (2006) recommend calculating the Skill Execution Index (SEI) based on the ratio of efficient to efficient plus inefficient actions. However, this method does not take into consideration the results of multiple observers, as in our study. To overcome this problem, it may be more appropriate to use the adjusted formula (see below), which considers the assessment of all the raters (k=1 to n) for efficient actions (a_e) and inefficient actions (a_i) and creates values from 0 to 2 for each coder (Memmert & Harvey, 2008). All results above 1 indicate that the player is successful and has shown more efficient than inefficient actions.

$$\mathrm{SEI} = 2x \frac{\sum_{k=1}^{n} (a_e + 1)}{\sum_{k=1}^{n} (a_e + a_i + 2)}$$

Declarative knowledge. The aim of this analysis was to check the instruction manipulation of the groups and to ensure that they learned through an implicit or explicit process. All participants were asked to fill out the Declarative Knowledge Questionnaire (Masters & Maxwell, 2004), before and after the learning phase, regarding all the rules, coaching tips, and strategies they felt were important for the execution of the shooting skill in basketball. The test was adapted for children aged 9 to 12 years and piloted with other children of the same age. Explicit rules were measured by comparing the number of written rules related to the position and/or movement of the feet, leg, body, arm, and the ball to a list of set instructions (Schroeder & Bauer, 2001). Two independent raters counted the number of explicit rules reported by each participant relating to motor skill execution (e.g., ‘‘I keep my forearm vertical” or “I extend my elbow when I shoot”). Statements that were irrelevant to technical performance such as “I bounce the ball two times before shooting” were not included. ICCs were computed to evaluate inter-rater reliability for declarative knowledge in the pre-test and post-test. Significant correlations were shown for both pre-test (ICC = .80, $p < .001$) and post-test (ICC = .94, $p < .001$), so means were calculated from the combined scores of the independent raters.

Procedures

The experiment comprised two distinct phases: a learning phase and a test phase.

Learning phase. The learning phase was presented as a "basketball camp" for the intervention groups (explicit, implicit, and sequential). We organized three “basketball camps”, one for each intervention group, which received different instructions according the learning process (see Table 2). For each camp, two basketball coaches were recruited and trained for their respective protocol. The learning phase took place over five consecutive days, during distinct school holidays. A total of eight units of 2.5 h each were performed in the learning phase, one unit on the first and last day of the camp and two units on each of the other days. In each unit one tactical problem and one technical skill were taught through implicit or explicit method, depending on the group in which the participant had been placed. About 30 min were spent practicing the technique and about 2 hours were spent performing tactical tasks that also required the execution of technical movements. The participants practiced the shooting movement in three different units. The training schedule is depicted in Table 1. The time for each activity was controlled and equal for all interventions groups.

Insert Table 1 here

The learning content and training structure were the same for all intervention groups. The training session was adapted from the book *Teaching Sport Concepts and Skills* (Mitchell et al., 2006) and included the tactical level of complexity I and II in basketball and the technical skills of chest pass, dribbling, and shooting. The three intervention groups differed only in terms of instruction, as we can see below.

Explicit learning group - The participants of this group followed an explicit protocol intervention program. The instructions about the tactical skills were taught through "guided discovery learning" (Raab, 2003), i.e., the coach asked questions to guide the solution to the tactical problem presented in the game. The questions were based on the suggestions made by Mitchell et al. (2006) and emphasized tactical awareness. Motor learning was introduced with a step-by-step method in which the technical skill outlined by Schroeder and Bauer (2001) was explained to the children in detail (see Table 2). These movement rules were read before and after the technical training. In addition, the main skill rules were repeated at the start and end of the day with all the children of the group together. In terms of feedback, the children were not corrected in relation to skill execution.

Insert Table 2 here

Implicit learning group - In the implicit group, children were given no instructions in terms of tactics or technique execution. The tactical skills were taught through the “non-guided learning” method, where players have to find unique solutions to movement problems through exploration and discovery. No instructions about tactical movements were given by the coach. The errorless approach was used to promote the implicit motor learning, such that participants started closer to the basket and slowly increased the distance from the basket. The implicit group did not get any feedback about skill execution.

Sequential learning group - The participants in this group followed the implicit learning protocol for the first four units and the explicit learning protocol for the four subsequent units.

Control group - The control group completed only the test phase (pre-test and post-test).

Test Phase

The test phase comprised the pre-test, the post-test, and a transfer test. The pre-test and post-test consisted of identical experimental procedures and conditions (e.g., period of the day, balls, etc.) and were counterbalanced across each condition for all groups. The pre-test was conducted prior to the start of the learning phase and the post-test and the transfer test on the day after the last training unit. The transfer test was a basketball game, in a 3-on-3 condition, on a half-court.

Data Analysis

Data were checked for normality and outliers (values representing more than two standard deviations). A two-way analysis of variance (ANOVA; 4 Groups × 2 Tests) with repeated measures on the last factor was used to compare the performance of the basketball shooting (isolate) and basketball shooting under game conditions among the four groups (Hypotheses 1 and 2, respectively). To test Hypothesis 1 we used the score of basketball shooting on the pre-test und post-test. To investigate the Hypothesis 2 we used the score on post-test of the basketball shooting (isolate) and the score on the transfer test (basketball shooting under game conditions). To test Hypothesis 3, concerning declarative knowledge, we used a one-way ANOVA to compare the four groups in the pre-test and post-test. A Scheffé post hoc test was used to explore significant ANOVA results further. The effect sizes were calculated as partial eta squared (η_p^2). The alpha level was .05. The statistical procedures were calculated with SPSS, version 20.

Results

The descriptive statistics for the dependent variables for each group are displayed in Table 3. The results section is structured following the sequence of the hypotheses.

Insert Table 3 here

Basketball shooting (Hypothesis 1)

Initial performance was assessed using a one-way ANOVA with the score of the pre-test. No initial significant differences were found between the groups, $F_{3,76} = 2.40$, $p = .075$. A Group × Test repeated-measures ANOVA, with number of scored points in the free-throw shooting test as a dependent measure, revealed significant main effects of test, $F_{1,76} = 4.82$, $p < .05$, $\eta_p^2 = .06$, and Group, $F_{3,76} = 2.86$, $p < .05$, $\eta_p^2 = .10$. Post hoc analysis indicated that the explicit group had a higher performance of basketball shooting than the control group ($p < .05$). No significant interactions, $F_{3,76} = 2.01$, $p = .119$, $\eta_p^2 = .07$, were found, meaning that all interventions groups improved in a similar manner as a consequence of practice (Figure 1). So, Hypothesis 1 was not supported.

Insert Figure 1 here

Basketball shooting under game conditions (Hypothesis 2)

To check the stability of the basketball shooting skill under cognitive constraints, we compared the performance of this skill in isolation and in a game (3 on 3). Only the values of the post-tests were used after they had been *z* transformed. The results of the 4 × 2 (Group × Test) ANOVA with repeated measures revealed a main effect of group, $F_{3,76} = 3.50$, $p < .05$, $\eta_p^2 = .12$. Post hoc comparisons between the four groups showed the control group performed at a significantly lower level than the explicit group ($p < .05$), but this difference already existed in the pre-test (ANOVA, $F_{1,76} = 3.76$, $p < .05$). As illustrated in Figure 2, it is apparent that the performance of the implicit group remained stable and the other groups' performance deteriorated under game conditions. Nevertheless no significant effect of test, $F_{1,76} = .942$, $p = .335$, or Group × Test interaction, $F_{3,76} = .342$, $p = .795$, was found. Thus, Hypothesis 2 was not supported.

Insert Figure 2 here

Declarative knowledge (Hypothesis 3)

To identify if the explicit method was successfully implemented, we ran a one-way ANOVA comparing the explicit rules reported by the groups before and after the intervention. Before they completed the program, no significant difference was found among the groups, $F_{3,71} = 1.78$, $p = .159$, but in the post-test there was a statistically significant difference, $F_{3,72} = 0.01$, $p < .001$. The post hoc analysis (Scheffé) revealed that the explicit and sequential groups reported more rules than the implicit and control groups (Figure 3).

Insert Figure 3 here

Discussion

In the present study, we examined the effect of explicit and implicit learning, as well as a sequential application of learning modes, in the acquisition of the basketball shooting skill. The current study extended previous work by combining training in several technical and tactical skills in a learning phase in an ecological setting. Furthermore, we tested the generalization of effects by testing a specific sports skill in children instead of adults. Finally the learning phase lasted 25h, much more than standard laboratory testing provides.

As expected, the results show that all intervention groups improved performance in the basketball shooting task from pre-test to post-test and the control group did not. Taking into account the combination of technical and tactical training of several skills (additional load) and the results of previous studies (Poolton et al., 2005; Tielemann, 2008), we had predicted that the implicit and sequential group would have a better shooting performance at the end of the learning phase. Despite the apparent better performance over time of the sequential group compared with the other groups, we did not find a significant interaction effect. However, a significant main effect (Group) was found between the explicit and control groups, in that the latter scored fewer points. From the beginning, both groups performed quite differently compared to the other groups that almost reached significance. During the learning phase, the variation between these groups became larger and statistically significant.

It can also be argued that environmental complexity in the learning phase was too high, considering that several technical and tactical skills were taught and about 20 children participated in the intervention program at the same time. According to Lebed and Bar-Eli (2013), a complex environment has a large number of elements, unpredictable behaviors, and many interactions of available information. Thus, in the sports context, the complexity of a situation increases when there is a small perceptual space–time relation (e.g., distance between players), when the number of options rises and their detectable differences decrease, and when the number of attributes used to define a situation and the relation between decisions and situations increases (Raab, 2003). Raab (2003) carried out four experiments with adults to investigate the interaction of implicit and explicit learning processes and complexity in the decision making of athletes in tactical team sports, including basketball. His results suggest that implicit learning is superior in high-complexity situations and explicit learning in low-complexity situations. Therefore, it is plausible that only the explicit learners in our study improved their performance by the end of the learning phase. However, because the focus in this study was more on motor learning and the participants were children, further studies are needed to test alternative explanations.

To replicate and extend the findings of several studies (Masters, Poolton, Maxwell, et al., 2008; Poolton et al., 2006; Tielemann, 2008), the second aim of this study was to test the robustness of the basketball shooting performance under cognitive constraints. The performance level of the implicit group continued to rise during transfer, despite the imposition of the game condition, supporting the hypothesis that this group was not using working memory to control aspects of the shooting task. The explicit and control groups suffered a drop in performance while performing the skill under cognitive constraints, reflecting their dependence on working memory to control the primary task. However, these changes in performance were not statistically significant and we could not confirm Hypothesis 2. Although the groups showed a similar performance in the transfer test, the analysis of declarative knowledge revealed that the sequential and explicit groups reported significantly more movement rules than the implicit and control groups. These results replicate previous work (see Masters & Poolton, 2012 for a review), and provide a manipulation check.

Thus, counter to our original prediction, there was no clear relationship evident between the number of rules reported and performance on the transfer test. Here it is important to highlight that only in the study of Tielemann (2008) did the transfer test involve a decision-making task, while in the other works the secondary cognitive task was to count pitched tones (Poolton et al., 2006) or to generate random letters (Masters, Poolton, & Maxwell, 2008). The present study extends previous research by its use of an ecological setting (3-on-3 basketball game), where motor and cognitive skills were required. Moreover, Tielemann (2008) used the analogy method to promote the implicit learning of a table tennis forehand in adults, whereas we employed the errorless method to implicitly teach children how to shoot a basketball. Due to these differences in the studies, it is difficult to compare the results or find a uni-dimensional explanation of the differences.

Limitations

Some limitations of this study should be noted. First, it was not possible to randomly assign individual children to an intervention group or the control group because the basketball camps (learning phase) occurred at different times due to external and organizational factors. An improvement would be to work with the three intervention groups and the control group in parallel, so that the children could be randomly assigned. Second, to favor the ecological validity of the study, it was not possible to control the errors of each participant in the shooting skill during the learning phase in the basketball camps. Nevertheless, we argue that the implicit motor learning was appropriately implemented due to the low numbers of movement rules reported by the participants in the implicit group. Another problem is related to the motivation of the participants in the learning phase and on the test day, especially in the post-test. After five consecutive days of basketball training (from 9:30 a.m. until 4:30 p.m.), some children were tired and not fully motivated on the 6th day, in the post-test. This condition may have had an influence on the test results, but it applies to all the intervention groups. An alternative would be to insert one day of rest between the learning and the test phase. Another possibility would consist in introducing a motivational test to determine if the various learning processes lead to different levels of motivation.

What does this article add?

We believe that, despite these limitations, the present study provides further knowledge on implicit and explicit learning processes in the field and extends the current literature on this topic. We adopted the novel approach of analyzing the effects of implicit and explicit learning in the acquisition of shooting in basketball in an ecological setting, where the children had to perform other actions besides shooting. The implicit learning showed no disadvantage when compared to explicit motor learning in complex environment. Moreover, the errorless paradigm was used for the first time with children to promote the implicit learning of a sport specific skill. It seems that this implicit paradigm was implement with success, since the children in this group reported very low number of movement rules. Continued research is required to determine how combined training (technical and tactical) in ecological settings, through implicit, explicit, or a combination of the two learning processes (sequential), can most benefit motor learning of sports skills. To examine the influence of further acquisition of declarative knowledge, we recommended that the participants of the sequential group should be tested for all dependent variables in the middle of the intervention, when the type of learning process changes.

References

Capio, C. M., Poolton, J. M., Sit, C. H. P., Eguia, K. F., & Masters, R. S. W. (2013). Reduction of errors during practice facilitates fundamental movement skill learning in children with intellectual disabilities. *Journal of Intellectual Disability Research, 57*(4), 295-305. doi:10.1111/j.1365-2788.2012.01535.x

Capio, C. M., Poolton, J. M., Sit, C. H. P., Holmstrom, M., & Masters, R. S. W. (2013). Reducing errors benefits the field-based learning of a fundamental movement skill in children. *Scandinavian Journal of Medicine & Science in Sports, 23*(2), 181-188. doi:10.1111/j.1600-0838.2011.01368.x

Côté, J., Murphy-Mills, J., & Abernethy, B. (2012). The development of skill in sport. In N. J. Hodges & M. Williams (Eds.), *Skill acquisition in sport: research, theory and practice* (pp. 269-286). London: Routledge.

Frensch, P. A. (1998). One concept, multiple meanings: on how to define the concept of implicit learning. In M. A. Stadler & P. A. Frensch (Eds.), *Handbook of implicit learning* (pp. 47-104). Thousand Oaks: Sage.

Hardy, I., & Parfitt, G. (1991). A catastrophe model of anxiety and performance. *British Journal of Psychology, 82*, 163-178.

Houwen, S., Visscher, C., Hartman, E., & Lemmink, K. A. (2007). Gross motor skills and sports participation of children with visual impairments. *Reserach Quarterly for Exercise and Sport, 78*(2), 16-23. doi:10.1080/02701367.2007.10762235

Kleynen, M., Braun, S. M., Bleijlevens, M. H., Lexis, M. A., Rasquin, S. M., Halfens, J., . . . Masters, R. S. W. (2014). Using a Delphi Technique to Seek Consensus Regarding

Definitions, Descriptions and Classification of Terms Related to Implicit and Explicit Forms of Motor Learning. *Plos One, 9*(6). doi:ARTN e10022710.1371/journal.pone.0100227

Kleynen, M., Braun, S. M., Rasquin, S. M. C., Bleijlevens, M. H. C., Lexis, M. A. S., Halfens, J., . . . Beurskens, A. J. (2015). Multidisciplinary Views on Applying Explicit and Implicit Motor Learning in Practice: An International Survey. *Plos One, 10*(8). doi:ARTN e013552210.1371/journal.pone.0135522

Koedijker, J. M., Oudejans, R. R. D., & Beek, P. J. (2008). Table tennis performance following explicit and analogy learning over 10,000 repetitions. *International Journal of Sport Psychology, 39*(3), 237-256.

Kröger, C., & Roth, K. (2005). *Ballschule - ein ABC für Spielanfänger [Ball scholl - an ABC for novice in games]*. Schorndorf: Hofmann.

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*(2), 179-191. doi:Pii 90790963810.1080/02640410802448764

Lebed, F., & Bar-Eli, M. (2013). *Complexity and control in team sports: Dialectics in contesting human systems*. London: Routledge.

Liao, C. M., & Masters, R. S. W. (2001). Analogy learning: a means to implicit motor learning. *Journal of Sports Sciences, 19*(5), 307-319. doi:10.1080/02640410152006081

Marasso, D., Laborde, S., Bardaglio, G., & Raab, M. (2014). A developmental perspective on decision making in sports. *International Review of Sport and Exercise Psychology, 7*(1), 251-273. doi:10.1080/1750984x.2014.932424

Masters, R. S. W. (2000). Theoretical aspects of implicit learning in sport. *International Journal of Sport Psychology, 31*(4), 530-541.

Masters, R. S. W. (2013). Practicing implicit motor learning In D. Farrow, J. Baker, & C. Macmahon (Eds.), *Developing sport expertise: researchers and coaches put theory into practice* (pp. 154-174). London: Routledge.

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: Research, theory and practice* (pp. 207-228). London: Routledge.

Masters, R. S. W., & Poolton, J. M. (2012). Advances in implicit motor learning. In N. J. Hodges & A. M. Williams (Eds.), *Skill acquisition in sport: Research, theory and practice* (pp. 59-75). London: Routledge.

Masters, R. S. W., Poolton, J. M., & Maxwell, J. P. (2008). Stable implicit motor processes despite aerobic locomotor fatigue. *Consciousness and Cognition, 17*(1), 335-338. doi:10.1016/j.concog.2007.03.009

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*(1), 71-79. doi:10.3200/Jmbr.40.1.71-80

Masters, R. S. W., Van der Kamp, J., & Capio, C. M. (2013). Implicit motor learning by children. In J. Côté & R. Lidor (Eds.), *Conditions of Children's Talent Development in Sport* (pp. 21-40). Morgantown, WV: Fitness Information Technology Publishing.

Maxwell, J. P., Masters, R. S. W., Kerr, E., & Weedon, E. (2001). The implicit benefit of learning without errors. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 54*(4), 1049-1068. doi:10.1080/02724980143000073

Memmert, D., & Harvey, S. (2008). The game performance assessment instrument (GPAI): some concerns and solutions for further development. *Journal of Teaching in Physical Education, 27*(2), 220-240.

Mitchell, S. A., Oslin, J. L., & Griffin, L. L. (2006). *Teaching sports concepts and skills: A tactical games approach* (2nd ed.). Champaign: Human Kinetics.

Oslin, J. L., Mitchell, S. A., & Griffin, L. L. (1998). The Game Performance Assessment Instrument (GPAI): Development and preliminary validation. *Journal of Teaching in Physical Education, 17*(2), 231-243.

Perreault, M. E., & French, K. E. (2015). External-Focus Feedback Benefits Free-Throw Learning in Children. *Research Quarterly for Exercise and Sport, 86*(4), 422-427. doi:10.1080/02701367.2015.1051613

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*(3), 362-378. doi:10.1016/j.humov.2005.06.006

Poolton, J. M., Masters, R. S. W., & Maxwell, J. P. (2006). The influence of analogy learning on decision-making in table tennis: Evidence from behavioural data. *Psychology of Sport and Exercise, 7*(6), 677-688. doi:10.1016/j.psychsport.2006.03.005

Poolton, J. M., Masters, R. S. W., & Maxwell, J. P. (2008). Passing thoughts on the evolutionary stability of implicit motor behaviour: Performance retention under physiological fatigue. *Consciousness and Cognition, 17*(1), 408-408. doi:10.1016/j.concog.2007.07.006

Raab, M. (2003). Implicit and explicit learning of decision making in sports is effected by complexity of situation. *International Journal of Sport Psychology, 34*(4), 273-288.

Raab, M., Lobinger, B., Hoffmann, S., Pizzera, A., & Laborde, S. (2016). *Performance Psychology – Beyond Domains*. Philadelphia: Elsevier.

Schlapkohl, N., Hohmann, T., & Raab, M. (2012). Effects of instructions on performance outcome and movement patterns for novices and experts in table tennis. *International Journal of Sport Psychology, 43*(6), 522-541. doi:10.7352/Ijsp2012.43.053

Schroeder, J., & Bauer, C. (2001). *Basketball: trainieren uns spielen [Basketball: training and play]*. Reinbek: Rowohlt.

Showalter, D. (2007). *Coaching youth basketball.* . Champaign: Human Kinetics.

Tielemann, N. (2008). *Modifikation motorischer Lernprozesse durch Instruktionen: Wirksamkeit von Analogien und Bewegungsregeln [Modification of motor learning processes through instruction: Effects of analogies and movement rules].* (Doctor), University of Flensburg, Flensburg.

Weigel, P., Raab, M., & Wollny, R. (2015). Tactical decision making in team sports - a model of cognitive processes. *International Journal of Sports Science, 5*(4), 128-138. doi:10.5923/j.sports.20150504.03

TABLES

Table 1. Example of a Training Schedule of One Unit for All Intervention Groups

Time	Activity
20 min	Warm-up activity + stretching
20 min	3 on 3 game (tactical problem)
30 min	Technical training
20 min	Small game
20 min	3 on 3 game (same tactical problem)
20 min	5 on 5 game
20 min	Pause (water break, explanations)

Table 2. Instructions Given in the Explicit Condition for Basketball Shooting

Explicit instructions
Keep your feet shoulder-width apart and knees slightly bent.
Point your feet point toward the basket.
Support the ball with the hand of your non-shooting arm.
Elbow of your shooting arm should be under the ball.
Stretch your body fully from the bottom up (toward the roof).
During shooting, the throwing arm stretches vertically upward.
Release the ball with your fingertips.
Follow through by snapping the wrist toward the basket, so that the shooting hand is facing downward.

Table 3. Descriptive Statistics for All Dependent Variables by Group

Dependent variables	Explicit		Implicit		Sequential		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Basketball shooting								
Pre-test	26.40	4.29	23.94	5.70	22.32	4.02	22.83	6.44
Post-test	27.60	5.30	24.89	6.12	26.05	6.11	22.39	6.48
Basketball shooting under game conditions								
Post-test[a]	0.58	0.91	0.12	1.05	0.32	1.05	-0.29	1.14
Transfer-test[a]	0.27	0.81	0.18	0.91	0.08	1.16	-0.36	0.96
Declarative knowledge								
Pre-test	0.44	0.46	0.14	0.28	0.26	0.45	0.17	0.48
Post-test	1.66	1.15	0.28	0.46	1.58	2.11	0.20	0.47

[a]*Z* score.

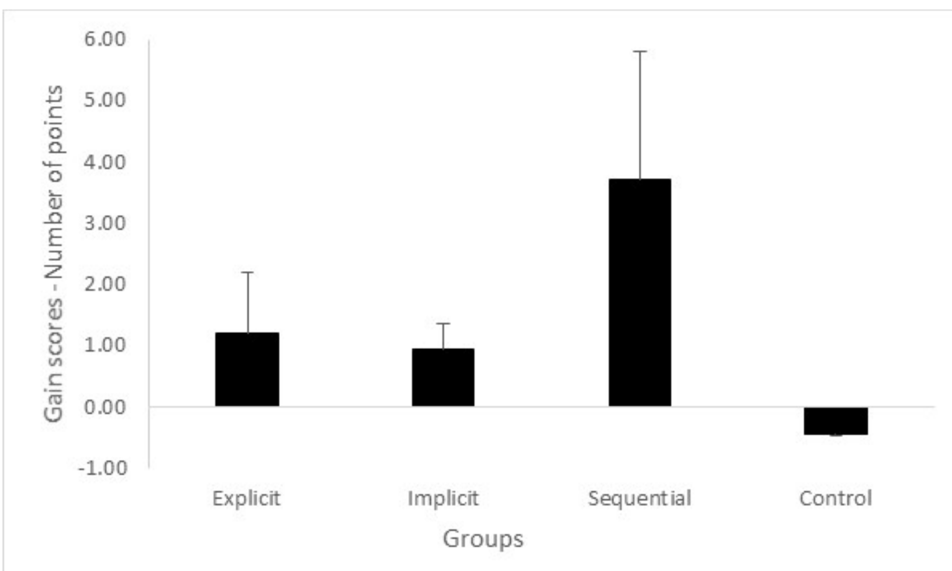

Figure 1. Gain scores between post-test and pre-test of the basketball shooting test by group. Error bars represent standard deviation.

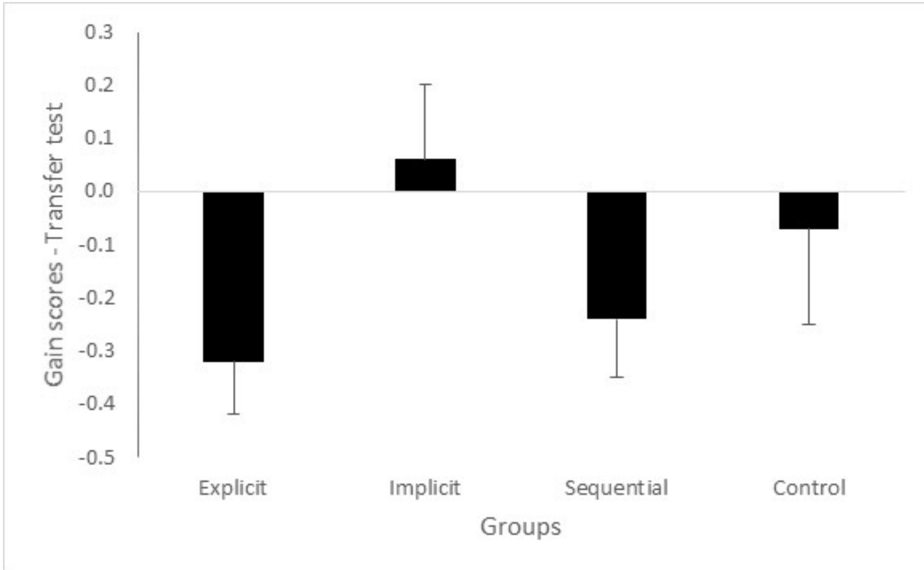

Figure 2. Gain scores between transfer test and post-test of the basketball shooting under decision-making constraints task by group. Error bars represent standard deviations.

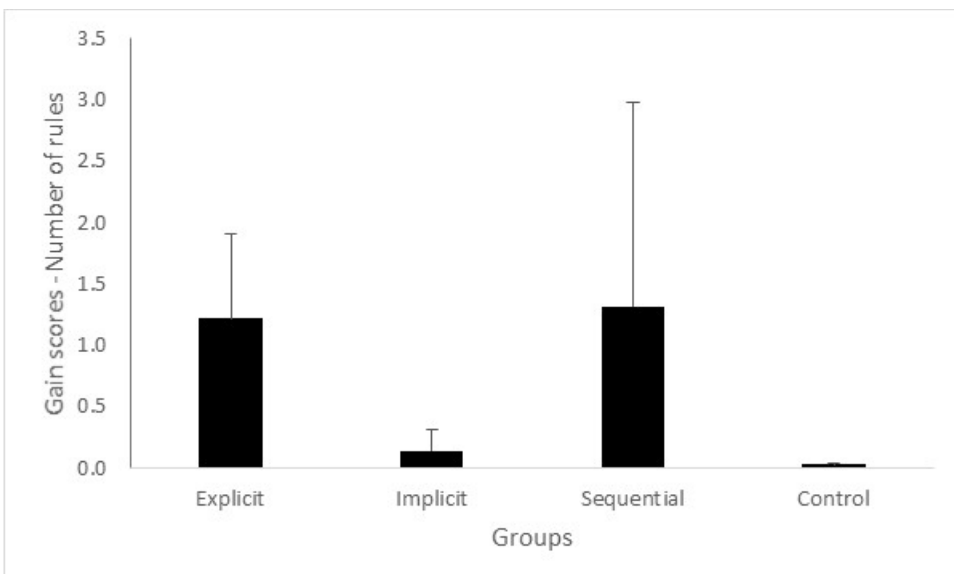

Figure 3. Gain scores between post-test and pre-test of the number of movement rules by group. Error bars represent standard deviations.