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The Development of a Culturally Appropriate Analogy for Implicit Motor Learning in a Chinese Population

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Learning a motor skill by analogy can benefit performers because the movement that is developed has characteristics of implicit motor learning: namely, movement robustness under pressure and secondary task distraction and limited accrual of explicit knowledge (Liao & Masters, 2001). At an applied level the advantages are lost, however, if the heuristic that underpins the analogy conveys abstractions that are inappropriate for the indigenous culture. The aim of the current experiment was to redevelop Masters's (2000) right-angled-triangle analogy to accommodate abstractions appropriate for Chinese learners. Novice Chinese participants learned to hit table tennis forehands with topspin using either a redeveloped, culturally appropriate analogy (analogy learning) or a set of 6 instructions relevant to hitting a topspin forehand in table tennis (explicit learning). Analogy learners accrued less explicit knowledge of the movements underlying their performance than explicit learners. In addition, a secondary task load disrupted the performance of explicit learners but not analogy learners. These findings indicate that a culturally relevant analogy can bring about implicit motor learning in a Chinese population.

The development of motor-learning techniques that benefit sport performers is naturally appealing to both coaches and sport psychologists. An approach that is receiving increasing attention is implicit motor learning (Masters, 1992; for a review see Masters & Maxwell, 2004), which has its roots in the cognitive psychology literature (for a review see Cleeremans, Destrebecqz, & Boyer, 1998; Dienes & Berry, 1997) and refers to a process by which people become more efficient at a task without necessarily intending to do so, and, in contrast to explicit learning, with little verbal knowledge of how they perform the task (Berry & Dienes, 1993). For example, in movement-tracking tasks, learners are seen to improve in their tracking capability on segments of the movement pattern that have been repeated across practice trials, despite being unaware that the segments repeat (e.g., Shea, Wulf, Whitacre, & Park, 2001).

Many of the characteristics that dissociate implicit from explicit learning in the cognitive literature are also evident in implicit *motor* learning, and these have considerable potential to benefit performers in sport. For instance, implicit motor

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learning has been shown to result in the minimal accumulation of explicit (verbalizable) knowledge of the movements constituting motor performance (e.g., Masters, 1992) and limited dependence on working memory (e.g., Maxwell, Masters, & Eves, 2003). (Working memory is assumed to be central to the storage, manipulation, and retrieval of explicit knowledge. Working memory, therefore, assists in the conscious implementation of verbal instructions and hypothesis-testing, or trial-and-error, behavior.) As a result, robust implicit motor performance has consistently been demonstrated under psychological pressure (e.g., Hardy, Mullen, & Jones, 1996; Masters, 1992) and even exercise-induced fatigue (Masters, Poolton, & Maxwell, in press; Poolton, Masters, & Maxwell, 2007).

Most of the implicit motor-learning paradigms that have been validated are not applicable in "real world" settings. One technique devised to bridge the gap between theory and practice is analogy learning (Law, Masters, Bray, Eves, & Bardswell, 2003; Liao & Masters, 2001; Masters, 2000), in which detailed explicit instructions about correct technique are substituted by an analogy. The analogy behaves like a "biomechanical metaphor" in that it describes the fundamental movement dynamics that underlie efficient technique. Although knowledge of the analogy itself is verbally accessible, knowledge of the underlying movement dynamics is not. Masters (2000) proposed that coaches should use analogies to encourage implicit motor learning by reducing the amount of explicit knowledge that the learner accumulates.

To examine whether analogy learning causes implicit motor learning, Liao and Masters (2001) asked native English-speaking participants to learn a table tennis topspin forehand by using a right-angled-triangle analogy; participants were instructed to "strike the ball while bringing the bat up the hypotenuse of the triangle" (p. 310). The performance of the analogy learners was compared with the performance of explicit learners who were instructed with 12 rules for a table tennis forehand. The analogy learners demonstrated robust performance under secondary task conditions designed to (over)load working memory (counting backward in 3s), implying that they had limited dependence on working memory for motor control. In contrast, the performance of explicit motor learners was disrupted by the secondary task, suggesting that motor control was dependent on working memory. Furthermore, the analogy learners reported fewer explicit rules regarding their movements and showed robust performance when asked to perform in stressful conditions induced by ego-threatening feedback. Liao and Masters concluded that analogy learning was an effective way to cause implicit motor learning. These findings have since been replicated by Law et al. (2003).

Work by Poolton, Masters, and Maxwell (2003), in which a literal translation of the analogy was used in a Hong Kong Chinese population, has raised doubts about whether the concept of a right-angled triangle confers understanding of the higher order constructs of a topspin forehand across all cultures. In the study, novice Hong Kong Chinese participants learned a topspin forehand using six rules (or technical instructions) that experienced coaches had rated as best representing the movement form induced by the right-angled triangle analogy. The rules were directly translated into Cantonese (and back-translated to confirm the accuracy of the translation). After a brief learning period (100 trials), participants were presented with the right-angled-triangle analogy and were asked to rely exclusively on the analogy during a 20-trial transfer block. Despite appearing to understand the geometric principles of a right-angled triangle and holding explicit knowledge of the underlying rule structure encapsulated by the analogy (i.e., 6 rules from the learning phase), participants nevertheless exhibited difficulty in mapping the principles of the analogical concept to their movements. As a result, performance significantly deteriorated in the transfer block. In postexperimental interviews most participants expressed confusion about how to implement the right-angled triangle analogy. Blowers (2000) argued that through language translation, cultures "indigenize" concepts in such a way that "ideas can be misunderstood through ignorance of the foreign culture" (p. 295). In other words, translating word for word ignores the norms of expressive communication in Chinese (Brislin, 1980).

If an analogy conveys inappropriate abstractions it cannot be applied effectively (Gentner, 1983), so the aim of this study was to present evidence for the redevelopment and validation of an analogy that accommodates abstractions appropriate for Chinese learners. Development of a culturally appropriate analogy was expected to result in findings that replicate those of Liao and Masters (2001), with participants displaying characteristics indicative of implicit motor learning. Specifically, we expected to see robust motor performance in participants concurrently processing a secondary task and limited accumulation of explicit knowledge.

Method

Consistent with the methods employed by Liao and Masters (2001), participants ($N = 28$) learned a table tennis topspin forehand by either receiving six instructions (explicit learning; $n = 14$) or by a single analogical instruction (analogy learning; $n = 14$). All participants were right-hand-dominant table tennis novices. Participants were classified as novices on the basis of having received no formal coaching and having no recollection of ever having played more than once a month. All spoke Cantonese as their first language (the experiment was conducted entirely in Cantonese).

The task required participants to hit balls, with topspin, to a target positioned at the far right-hand corner of a standard table tennis table. The target consisted of two concentric squares. The outermost square was 75 cm wide, and the inner square 25 cm wide. Three points were awarded for balls landing in the inner square, 2 points for the outer square, and 1 point for a ball hitting any other part of the opposing end of the table. The table tennis balls (40 mm) were served with backspin to the right-hand side of the table by a Newgy Robo-pong 2000 ball-serving machine, at a frequency of 30 balls/min. All participants were required to hold the bat using the Western "shake hands" grip (Sneyd, 1994).

The experiment comprised two distinct phases: a learning phase and a test phase. Learning consisted of 300 trials partitioned into fifteen 20-trial blocks. Participants in the analogy-learning condition used an analogy designed to be culturally appropriate. The analogy was developed in collaboration with native Cantonese speakers using the right-angled-triangle analogy as a departure point. The analogy instructed participants to "move the bat as though it is traveling up the side of a mountain." Participants in the explicit-learning condition received six specific instructions ordinarily used by coaches (Sneyd, 1994; The Sport Council, 1995) regarding the correct biomechanical rules to use. The instructions were as follows[1]: (a) Keep your feet a little wider than shoulder width apart, (b) position your feet behind the table with the right foot farthest from the table, (c) move the bat backward and down, (d) move your body weight to the front leg, (e) move your playing arm forward and upward, and (f) keep the bat face at a vertical angle. The explicit instructions were translated into Cantonese and then back-translated to verify their interpretation, consistent with current recommendations for cross-cultural research (Brislin, 1980; Duda & Hayashi, 1998). Participants were reminded of the analogy or explicit instructions before each block of learning. The importance of performance accuracy and application of topspin was emphasized. At no point was the technique of the motor skill demonstrated. After learning, participants were given a 15-min rest period in which they completed an explicit knowledge protocol (Masters, 1992). The protocol required a detailed report of any methods, movements, or techniques participants remembered using to effectively perform the task.

Results

Learning Phase

The effect of the two treatment conditions on learning was assessed by computing a Group × Block (2 × 15) ANOVA with repeated measures on the latter factor, reporting Greenhouse–Geisser corrections when sphericity was violated. Total number of points scored in each block of learning was taken as the dependent variable. A significant main effect of block, $F(6.67, 173.41) = 11.00$, $p < .001$, $\eta^2 = .30$, was shown, but neither an effect of group nor an interaction was evident (both $p > .05$). As illustrated in Figure 1, the results suggest that the performance of both groups improved similarly as a consequence of practice.

Explicit-Knowledge Protocols

Analysis of the explicit knowledge protocols that were completed after learning suggests that, although performance in the two treatment conditions was similar,

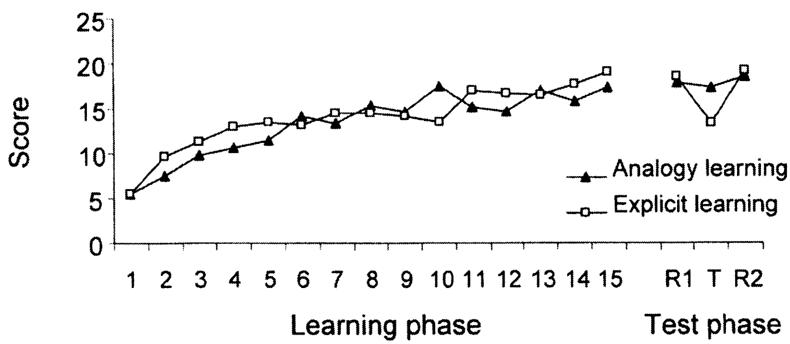

Figure 1 — Points scored in the explicit and analogy learning conditions during the learning phase and during the retention tests (R1 and R2) and transfer test (T).

the knowledge available for verbal recall differed. Rules that were related to the mechanics of the movement (e.g., "I kept the bat in a vertical position throughout the swing" or "I moved my arm from a low to a high position") were counted independently by two scorers. Intraclass correlation coefficients showed high inter-rater reliability (ICC = .89, $p < .001$). Means were therefore calculated from the collective scores of the independent raters and assessed by an independent-samples t test. A significant difference was shown, $t(26) = -4.01$, $p < .001$. Participants in the explicit condition reported significantly more mechanical rules ($M = 5.75$ rules) than participants in the analogy-learning condition ($M = 3.29$ rules). This finding indicates that learning by analogy suppressed the accrual of explicit knowledge.

Test Phase

Performance in the test phase was assessed by a Group × Block (2 × 3) ANOVA with repeated measures. The analysis did not reveal a group effect, $F(1, 26) = .09$, $p = .77$, $\eta^2 = .003$, but did reveal a significant main effect of block, $F(1.57, 40.87) = 11.34$, $p < .001$, $\eta^2 = .30$, and an interaction between group and block, $F(1.57, 40.87) = 5.69$, $p < .05$, $\eta^2 = .18$. A posteriori analysis to identify the cause of the Group × Block interaction showed a simple main effect of block in only the explicit condition, $F(2, 26) = 13.08$, $p < .001$, $\eta^2 = .50$. Pairwise comparisons showed that motor performance in the transfer test (i.e., when concurrently performing the secondary task) was inferior to performance in both retention tests (both $p < .005$). No simple main effect of block was evident in the analogy-learning condition, $F(2, 26) = .81$, $p = .46$, $\eta^2 = .06$.

Discussion

The findings from the test phase indicate that the requirement to carry out a concurrent secondary task caused a breakdown of explicit learners' topspin forehand performance but had no effect on performance of participants who learned by analogy. The secondary task was used to evaluate the extent to which performers consciously controlled their movements. A breakdown in performance suggests that performers ordinarily relied on explicit knowledge to control movement, whereas robust performance, a characteristic of implicit learning (e.g., Maxwell et al., 2003), suggests independence from conscious processes (i.e., working memory). Furthermore, analysis of the explicit knowledge protocols implied that analogy learners had reduced awareness of the movement dynamics that constituted their motor performance. The culturally relevant analogy appeared, therefore, to result in motor performance with characteristics of implicit motor learning.

Alternative explanations have been proposed for the robust performance of analogy learners when processing a secondary task (see Masters, Poolton, Maxwell, & Raab, in press; Poolton, Masters, & Maxwell, 2006). One possibility is that the single analogical instruction moderates the processing demands on our limited-capacity working-memory system, thus leaving adequate resources available to process a second cognitive task. A second possibility is that the analogy might be accessed via a module of working memory (e.g., visuospatial sketchpad) separate from those required to process verbal information (Liao & Masters, 2001). Alternatively, the analogy might effectively "chunk" components of the motor act together, allowing for early development of movement automaticity (Masters & Liao, 2003). Finally, the reduced processing requirements of the analogy might better equip performers to switch between and effectively perform the motor and cognitive tasks. It is clear that further work is necessary to clarify the mechanisms that allow analogy learning to help performers when distracted by a secondary task.

Of additional interest is the similar pattern of learning in the two conditions. This finding supports the proposition of Masters (2000) and Liao and Masters (2001) that analogy learning, while conferring implicit-learning characteristics, allows motor-skill acquisition to occur at a rate equivalent to that of explicit learning. The finding is important at an applied level given that, historically, implicit motor-learning paradigms have tended to result in acquisition that is slower than verbal instruction or discovery learning (e.g., Maxwell, Masters, & Eves, 2000), possibly because of implicit paradigms reducing the learner's ability to correct erroneous motor performances (Baddeley & Wilson, 1994; Maxwell, Masters, Kerr, & Weedon, 2001).

In sum, it appears that the modified analogy is culturally suited to communicate higher order relationships among the biomechanical movement rules underlying the topspin forehand in table tennis. Consistent with findings in the cognitive-science domain (Donnelly & McDaniel, 1993), individuals were able to apply the analogy to learn the task but had limited ability to report basic biomechanical knowledge underlying the concept.

From an applied perspective, it is important that coaches adapt analogical instructions to suit the cultural and individual nuances of the performer and take care when they deliver analogical instructions. Coaches often perform a physical demonstration alongside verbal instructions to aid communication of technical information. However, observation of a demonstration that accompanies an analogical instruction might encourage the learner to develop an explicit verbal description of the underlying movement dynamics of the skill (Bandura, 1977), which can be disadvantageous. As a general rule, to take advantage of implicit-learning characteristics, coaches need to develop teaching methods that prevent learners from becoming overly aware of the underlying mechanics of their movements.

Note

1. The Cantonese translation of the analogy and the explicit instructions can be obtained by correspondence with the first author. After the rest period, participants performed in a test phase that consisted of a retention test, followed by a transfer test, and a second retention test. Each test was separated by a 3-min rest period and composed of two 20-trial blocks (scores from the two blocks were averaged for analysis). In retention, no instructions were given and participants were simply asked to do their best. In transfer, participants were required to perform the table tennis task while concurrently performing a second task in which they continuously counted backward in 7s from a four-digit number (Block 1: 1,584; Block 2: 2,550).

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