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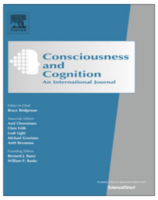

Scaling sporting equipment for children promotes implicit processes during performance

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ABSTRACT

This study investigated whether children who used scaled equipment compared to full size equipment during a motor task demonstrated reduced conscious involvement in performance. Children (9–11 years) performed a tennis hitting task in two attention conditions (single-task and dual-task) using two types of equipment (scaled and full size). A more skilled group and a less skilled group were formed using hitting performance scores. The more skilled group displayed greater working memory capacity than the less skilled group. For both groups, hitting performance and technique were better when scaled equipment was used. Hitting performance when using scaled equipment was not disrupted in either group by a cognitively demanding secondary task; however, performance was disrupted in the less skilled group when using full size equipment. We conclude that equipment scaling may reduce working memory engagement in motor performance and discuss the findings in the context of implicit motor learning theory.

1. Introduction

Cognitive models of learning (e.g., Fitts & Posner, 1976) suggest that learning a motor skill is initially a conscious process, and only after prolonged repetition does skill performance become unconscious (i.e., automatic control). The initial cognitive stage is characterised by the formulation of rules about how the skill should be performed. As such, explicit rule-maps develop that can be applied during future performances of the skill (Maxwell, Masters, & Eves, 2003). Formulation of rules, via processes such as 'hypothesis testing', occurs in working memory – the mechanism responsible for the processing and storing verbal, visual and episodic information during a cognitive task (Baddeley, 2012; Baddeley & Hitch, 1974; Gathercole, 2008; Miyake & Shah, 1999). Masters and colleagues (e.g., Masters, 1992; Maxwell et al., 2003; Poolton, Masters, & Maxwell, 2007) argued that a conscious mode of learning is heavily dependent on the availability of working memory resources. Consequently, the learner becomes reliant on working memory to execute the skill, which becomes problematic in situations that demand working memory resources. In such cases, if working memory is preoccupied with

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information unrelated to the skill itself, performance of the motor skill can deteriorate (MacMahon & Masters, 2002; Maxwell et al., 2003).

Another challenge for learner's, particularly children, is that working memory capacity is still developing throughout childhood (e.g., Alloway, Gathercole, & Pickering, 2006; Gathercole, Pickering, Ambridge, & Wearing, 2004; Luciana, Conklin, Hooper, & Yarger, 2005; Luna, Garver, Urban, Lazar, & Sweeney, 2004; Thomason et al., 2009). Children process information slower than adults (Ferguson & Bowey, 2005), and therefore it is unlikely that children learn as effectively via conscious methods as adults do. Indeed, the sensorimotor hypothesis suggests that young children rely more on implicit (unconscious) memory than explicit (conscious) memory to learn skills, whereas the opposite occurs for adults (e.g., Hernandez & Li, 2007; Hernandez, Mattarella-Micke, Redding, Woods, & Beilock, 2011). Thus, to optimise motor learning in children, practice should be designed to minimise explicit, working memory involvement in the learning process (e.g., Capio, Poolton, Sit, Holmstrom, & Masters, 2013). Implicit motor learning theory provides a framework for such practice (for a recent review of implicit motor learning, see Masters & Poolton, 2012).

Implicit motor learning refers to the acquisition of a skill with little to no conscious awareness of the information that underlies the learnt behaviour (Hardy, Mullen, & Jones, 1996; Magill, 1998; Masters, 1992; Pew, 1974; Reed, McLeod, & Dienes, 2010); hence, learning occurs with minimal working memory involvement (Maxwell et al., 2003). Several practice techniques have been proposed that aim to promote implicit motor learning (e.g., analogy learning, Liao & Masters, 2001; dual-task practice, Maxwell, Masters, & Eves, 2000; errorless practice, Maxwell, Masters, Kerr, & Weedon, 2001; marginally perceptible feedback, Masters, Maxwell, & Eves, 2009; and reduced feedback, Maxwell et al., 2003). For children, an approach that may encourage implicit rather than explicit learning is to use scaled equipment. Scaling equipment to suit the physical size of children allows skills to be performed with greater ease (Burton & Welch, 1990; Buszard, Farrow, Reid, & Masters, 2014; Elliott, 1981; Elliott & Marsh, 1989; Farrow & Reid, 2010; Hammond & Smith, 2006; Wright, 1967). Based on the errorless learning paradigm, which suggests that the reduction of errors during performance limits explicit hypothesis testing (Masters, MacMahon, & Pall, 2004; Maxwell et al., 2001; Orrell, Eves, & Masters, 2006; Poolton, Masters, & Maxwell, 2005; Poolton et al., 2007), we predict that scaling equipment will reduce working involvement during skill performance.

Maxwell et al. (2001) demonstrated the implicit learning benefits of errorless practice during a golf putting task. Participants who experienced many errors made more alterations to their technique and accumulated numerous rules about the skill. Subsequently, they performed significantly worse when required to concurrently perform a cognitively demanding secondary task. Maxwell et al. (2001) argued that errors cause a person to test hypotheses about potential movement solutions, which consequently places additional demands on working memory resources. Comparatively, participants who experienced limited errors during practice made fewer alterations to their technique, reported less rules and displayed performance that was not disrupted by a secondary task. This suggests that they did not test hypotheses about potential movement solutions and therefore were less reliant on working memory resources to perform the skill. This argument has since been supported by research in children learning to throw (Capio, Poolton, Sit, Euiga, & Masters, 2013; Capio, Poolton, Sit, Holmstrom, & et al., 2013), golf putting (e.g., Poolton et al., 2005), and patients rehabilitating from stroke (Orrell et al., 2006) and Parkinson's disease (Masters et al., 2004). It therefore appears that hypothesis testing is less likely to occur when skills are executed successfully. In the Maxwell et al. (2001) study, an 'errorless' practice environment was created by initially putting the golf ball from a very short distance and then gradually increasing the putt length. We propose that another method to achieve a relatively errorless environment is to modify the equipment used in order to increase the probability of successful outcomes. For example, Wulf, Shea, and Whitacre (1998) improved performance on a ski simulator by providing 'poles' to assist the participants' balance. Whilst achieving a 'true' errorless environment through equipment scaling is improbable, as children will always make mistakes, we predicted that there would be fewer demands on working memory resources when using scaled equipment compared to when using full size (adult) equipment.

Indeed, designing practice techniques that minimise working memory involvement may be most beneficial for children with low motor skill ability (e.g., Capio, Poolton, Sit, Euiga, & et al., 2013), as studies have shown that children with developmental coordination disorders typically also have underdeveloped working memory resources (e.g., Alloway, 2007b; Alloway & Archibald, 2008). Although we did not target movement-impaired children in the current study, we did divide children into skilled and less skilled groups based on their hitting performance and measured their working memory capacity to assess whether differences in cognitive development also existed between the groups. We hypothesised that skilled children would display higher scores on the working memory assessment, indicating greater working memory capacity. Consequently, we predicted that less skilled children would display greater performance disruption in a dual-task condition than more skilled children when using equipment that placed higher demands on working memory resources (i.e., full size equipment). In support of the claim that using full size equipment would place greater demands on working memory, we expected that children would make more alterations to their technique when using full size equipment compared to scaled equipment, as previous research has associated this with greater conscious processing (Maxwell et al., 2001; Poolton et al., 2005). Finally, we expected that all children would hit more accurately, and with better technique, when using scaled equipment compared to full size equipment, thus demonstrating the benefits of scaled equipment for all children, regardless of skill level or working memory capacity.