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Children's age modulates the effect of part and whole practice in motor learning

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ABSTRACT

Motor skills can be learned by practicing the whole or part of a movement. In whole practice (WP), a skill is acquired by practicing the movement in its entirety, whereas in part practice (PP), a task is learned by practicing its components before combining them. However, the effectiveness of WP and PP in children is unclear. We, therefore, examined the effects of WP and PP on the learning of juggling among first-, third-, and fifth-graders. Children of each grade were pseudo-randomly assigned to the WP or PP group to learn cascade juggling in 6 days. After baseline assessments, the WP learners practiced three-beanbag juggling. The PP learners practiced one-beanbag juggling on the first 2 days, two-beanbag juggling on the following 2 days, and three-beanbag juggling on the last 2 days. Practice consisted of 40 trials each day. Skill retention and transfer trials (juggling in the opposite direction) were measured 24 h after training (number of catches). There was no significant difference between WP and PP in skill retention (WP: 1.28 ± 0.73; PP: 1.42 ± 046, $p = .40$) and transfer (WP: 1.31 ± 0.78; PP: 1.37 ± 0.55, $p = .49$). However, a time $\times$ grade $\times$ group interaction ($p < .001$) was observed in retention. Children of different grades received differential benefits from the WP and PP regimens. The fifth-graders learned better using WP, whereas the first- and third-graders showed better learning with PP. We discuss the three possible explanations for the results (neural maturity, explicit learning, and coordination capabilities).

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Research into practice modes for skill learning has important developmental and pedagogical implications (Yan, Thomas, & Thomas, 1998). Specifically, motor skills can be learned in parts or as a whole. Part practice (PP) refers to the learning of separate components of a skill, one part at a time, before combining them all. Whole practice (WP), on the other hand, is learning a skill in its entirety, all at once (Magill & Anderson, 2013). Conceivably, by breaking down a skill into smaller parts, the physical and cognitive demands placed on a learner can be reduced for more effective learning. However, learning is a complex process. The optimal learning effect can be obtained only when the type of practice specifically fits the characteristics of the learner and the skill to be learned (Newell, 1991). In addition, childhood is a period of remarkable changes in cognitive and motor competence. It is important to consider the dynamics of age, motor experience, and task characteristics before deciding on the optimal learning strategy (Yan et al., 1998). Therefore, questions remain about the best practice mode for skill learning in children. Depending on skill characteristics, PP and WP can yield different learning benefits for particular motor skills.

According to the Cognitive Load Theory (CLT; Wickens, Hutchins, Carolan, & Cumming, 2013), there are three sources of cognitive load during learning. The intrinsic load is the information processing demand of the target task to learn, the extraneous load is the distraction, and the germane load is the investment of effort by the learner. CLT posits that these loads rely heavily on learners' working memory (Wickens et al., 2013). Naylor and Briggs (1963) suggested that task complexity and skill organization are the key factors to consider for planning and implementing a practice mode. The complexity and skill organization of Naylor and Briggs's proposal (1963) should correspond to the intrinsic load of CLT (Wickens et al., 2013). The task complexity describes the cognitive and motor demands placed on a performer (Kuriyama, Stickgold, & Walker, 2004; Meister et al., 2005; Wulf & Shea, 2002), with more complex tasks placing more demands on the information processing speed and capacity. For instance, driving is more complex than finger tapping. Skill organization describes the inter-dependence between the components of a skill (Fontana, Mazzardo, Furtado, & Gallagher, 2009), with greater organization minimizing the demands on information processing because of greater predictability about how the components will interact with each other. For example, juggling requires greater inter-limb coordination between the hands than throwing does. Magill and Anderson (2013), Naylor and Briggs (1963) suggested that PP would be optimal for learning skills of high complexity and low organization, whereas WP may yield superior results in learning skills of low complexity and high organization. College-age adults learn juggling better with WP than with PP (Knapp & Dixon, 1952). In acquiring a bimanual coordination task, training both hands simultaneously (WP) shows less spatial interference (as observed in drawing lines of different orientations with two hands) than training one hand at a time (PP) (Wenderoth, Puttemans, Vangheluwe, & Swinnen, 2003). Furthermore, in older adults, WP results in more time-efficient, forceful and smoother movements than PP for the acquisition of a three-step signature task (to reach for a pen, bring a pen to a paper, and sign the name; Ma & Trombly, 2001). The findings show WP superiority for learning motor skills that are relatively low in complexity and relatively high in organization.

In adults' motor learning, the differential benefits of WP and PP are associated with skill characteristics (Naylor & Briggs, 1963). Although both WP and PP enhance the learning of certain motor skills, it does not necessarily mean that *children* of different ages benefit similarly from WP and PP. Children normally have lower cognitive or motor capabilities than adults (Gathercole, Pickering, Ambridge, & Wearing, 2004; Hale, Bronik, & Fry, 1997). Consequently, children may show unique developmental characteristics in motor learning (Thomas, Yan, & Stelmach, 2000; Yan, Thomas, & Payne, 2002; Yan, Thomas, Stelmach, & Thomas, 2000). A better understanding of the relative effects of WP and PP in children of different ages results in optimal and specific teaching approaches. This was the purpose of the present experiment.

Motor learning poses varying cognitive demands on children of different ages. Younger children have lower information processing ability (Hale et al., 1997). Based on CLT (Wickens et al., 2013), due to younger children's information processing limitations, they may experience greater intrinsic loads than older children in learning the same motor skill. Therefore, the learning outcomes of children in response to WP or PP may differ. Examining the learning outcomes of PP and WP in children may provide teachers and coaches with valuable pedagogical information. The results may help