Human Movement Science 31 (2012) 801–810

Contents lists available at SciVerse ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Age-related differences in predictive response timing in children: Evidence from regularly relative to irregularly paced reaction time performance

Julie Debrabant [a,*], Freja Gheysen [a,b], Guy Vingerhoets [c], Hilde Van Waelvelde [a]

[a] Department of Rehabilitation Sciences and Physiotherapy, Ghent University and Artevelde University College, Campus Heymans, Ghent University, 2B3 (REVAKI), De Pintelaan 185, B-9000 Ghent, Belgium
[b] Department of Experimental Psychology, Ghent University, Henri Dunantlaan 2, B-9000 Ghent, Belgium
[c] Department of Internal Medicine, Ghent University, Proeftuinstraat 86, N8, B-9000 Ghent, Belgium

ARTICLE INFO

Article history:
Available online 10 April 2012

PsycINFO classification:
2221
2330

Keywords:
Timing
Motor development
Children
Reaction time
Motor processes

ABSTRACT

Predictive timing refers to the anticipation and precise timing of planned motor responses. This study was performed to investigate children's predictive response timing abilities while accounting for confounding age-related effects of motor speed. Indices of predictive timing were evaluated for their contributions in motor skill proficiency as well. Eighty typically developing children in 4 age groups (5–6, 7–8, 9–10 and 11–12 years) performed a visuomotor reaction time (RT) test. Differences in speed and anticipatory responding at regularly relative to irregularly paced stimuli were evaluated as indices of predictive timing. Also, explicit timing and motor tests (M-ABC-2, VMI tracing, and KTK jumping) were administered. Significant faster responding for regularly versus irregularly paced stimuli was found from the ages of 9–10 years on. Better anticipatory responding behavior for regular in contrast with irregular stimuli was found to be present already at 7–8 years. Overall, predictive timing abilities increased across the 4 age groups. Also, inter-individual differences in the speed indices of predictive timing contributed to predicting VMI tracing and KTK jumping outcomes when controlling for age and overall motor response speed. In conclusion, predictive motor timing abilities increase during age 5 to 12 and correlate with motor skill performance.

* Corresponding author. Tel.: +32 09 332 69 23; fax: +32 09 332 38 11.
E-mail addresses: Julie.debrabant@ugent.be (J. Debrabant), freja.gheysen@ugent.be (F. Gheysen), guy.vingerhoets@ugent.be (G. Vingerhoets), hilde.vanwaelvelde@ugent.be (H. Van Waelvelde).

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http://dx.doi.org/10.1016/j.humov.2011.09.006

1. Introduction

The development of motor skills involves a movement repertoire that can be flexibly tailored to different and specific task demands (Clark, 2005). Typically, the acquisition of motor skills in children takes place through play and imitation. For instance, with repeated practice, children acquire accurate temporal predictions of motor actions (e.g., adopting a pace when running, rhythmic sequencing when typing or playing music). This learning of temporal sensorimotor information is necessary for adequate motor skill performance and thus might reflect one of the crucial processes underlying typical motor development (Salthouse & Davis, 2006). The present study investigated age-related differences in predictive response timing in typically developing children.

Accurate predictive response timing is reflected in speeded and anticipatory motor behavior due to temporal regularities in the occurrence of stimulus events. At regularly paced or rhythmic stimulus sequences, motor performance is considered to be predictive when RTs are faster relative to RTs at irregularly paced stimuli. In the latter case, RTs result from a passive feedback response mode (Pollok, Gross, Kamp, & Schnitzler, 2008; Sakai et al., 2000). Although predictive timing received a great deal of interest from adult literature (Dreher, Koechlin, Ali, & Grafman, 2002; Martin, Houck, Kicic, & Tesche, 2008; Piras & Coull, 2011; Pollok et al., 2008; Sakai et al., 2000), little is known about children's predictive response timing abilities.

When focusing on the development of children's simple RT performance, which is often used as a measure of response or processing speed, overall improvement (i.e., decrease) in RT performance throughout childhood is consistently reported (Iida, Miyazaki, & Uchida, 2010; McAuley & White, 2011). However, this age-related RT effect may also be determined in part by stimulus timing effects. Especially studies using a regularly paced task design may confound age-related changes in feedback based response effects with age-related changes in predictive response effects. To what extent children's RT performance at regularly paced stimuli benefits from temporal predictability and thus becomes predictive, is unclear. Other studies exclude all possible effects of predictive responding by using an irregularly paced RT task design (Kiselev, Espy, & Sheffield, 2009; McAuley & White, 2011). Consequently, knowledge on predictive response timing abilities in children is lacking in current developmental literature.

If predictive timing in children is age dependent, responding at temporally predictable events will result in speeding up effects in addition to general response speed effects across age. Indirect evidence for this hypothesis is drawn from developmental studies that investigated children's abilities to synchronize with rhythmic patterns (Mastrokalou & Hatziharistos, 2007; McAuley & White, 2011). Synchronizing involves temporal encoding abilities that might not have been fully developed yet in young children. Synchronizing at isochronously (fixed) visual or auditory stimulus rates around 800 to 1500 ms is found to be sensitive in identifying age-related differences in children samples of 3 to 12 years (Kumai & Sugai, 1997; Mastrokalou & Hatziharistos, 2007; McAuley, Jones, Holub, Johnston, & Miller, 2006; Sasaki, 1997). In these studies, time differences between a child's response and the onset of the rhythmic pulse were calculated with shorter differences indicating better synchronizing.

In order to disentangle age-related RT effects adopted from a feedback based and predictive response mode, the present study compares RT performance respectively at irregularly and regularly paced visual stimuli. Since both interval types only differ in their temporal properties, predictive timing can be evaluated. To the best of our knowledge, this is the first developmental study using such design to study predictive response timing in an unconfounded way. Moreover, this kind of visuomotor RT task involves simple stimulus-response mappings and visuospatial processing; children are thus expected to rapidly learn to respond. Different response timing indices can be deduced from an analysis of resulting RT performances. RT reduction at regularly versus irregularly paced stimuli can be used as a behavioral index of predictive timing abilities, i.e., the greater the RT decrease, the more predictive the RT performance (Pollok et al., 2008; Takano & Miyake, 2007). In addition, the occurrence of anticipatory responses, typically defined as RT beneath 100 ms (Willingham, Nissen, & Bullemer, 1989), indicates that they are planned and initiated in advance of target appearance. The ability to produce anticipated responses serves as an index of the precision of voluntary motor responses initiated in omission of external sensory guidance. Furthermore, increasing effects across