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## Is processing of symbols and words influenced by writing system? Evidence from Chinese, Korean, English, and Greek



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### ABSTRACT

We examined cross-linguistic effects in the relationship between serial and discrete versions of digit naming and word reading. In total, 113 Mandarin-speaking Chinese children, 100 Korean children, 112 English-speaking Canadian children, and 108 Greek children in Grade 3 were administered tasks of serial and discrete naming of words and digits. Interrelations among tasks indicated that the link between rapid naming and reading is largely determined by the format of the tasks across orthographies. Multigroup path analyses with discrete and serial word reading as dependent variables revealed commonalities as well as significant differences between writing systems. The path coefficient from discrete digits to discrete words was greater for the more transparent orthographies, consistent with more efficient sight-word processing. The effect of discrete word reading on serial word reading was stronger in alphabetic languages, where there was also a suppressive effect of discrete digit naming. However, the effect of serial digit naming on serial word reading did not differ among the

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four language groups. This pattern of relationships challenges a universal account of reading fluency acquisition while upholding a universal role of rapid serial naming, further distinguishing between multi-element interword and intraword processing.

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## Introduction

Rapid automatized naming (RAN) is a strong predictor of reading fluency across orthographies (e.g., Cho & Chiu, 2015; de Jong, 2011; Georgiou, Aro, Liao, & Parrila, 2016; Moll, Fussenegger, Willburger, & Landerl, 2009; Parrila, Kirby, & McQuarrie, 2004; Wei, Georgiou, & Deng, 2015). Researchers have argued that the relationship between RAN and reading can reveal important information on how words are processed and, most important, how reading fluency is achieved, drawing a distinction between serial naming and discrete naming and how they relate to word reading (e.g., de Jong, 2011; Protopapas, Altani, & Georgiou, 2013a). In serial naming (i.e., RAN), items are presented simultaneously on a grid and the participant must process them sequentially, traversing the grid at an endogenously controlled rate. In contrast, in discrete naming, items are presented individually on the screen for participants to name and then wait for the next item to appear.

### *Differential associations with serial and discrete naming*

The serial format produces shorter total naming times than discrete naming; that is, a *serial advantage* is observed, at least for typical readers (Zoccolotti et al., 2013). In addition, it has long been noted that reading fluency correlates more strongly with serial naming than with discrete naming (Wolf & Bowers, 1999); this *serial superiority effect* has been recently confirmed across languages for readers past the beginner stage (e.g., de Jong, 2011; Protopapas et al., 2013a; van den Boer, Georgiou, & de Jong, 2016). The crucial distinction between serial and discrete naming is thought to concern sequential processing, that is, skill in the serial processing of successive stimuli. In other words, serial naming requires all processes involved in discrete naming and also serial scanning of the array and rapid processing of multiple stimuli in the order they are displayed. Therefore, discrete naming can assess the efficiency of verbal responses to unitary visual stimuli, whereas RAN can be used as a measure of serial processing skill over and above discrete naming. Consequently, correlations with RAN, controlling for discrete naming, can be used as indexes of serial processing. Alternative explanations of the serial superiority effect invoking effects of executive function or visual scanning direction have failed to account for the observed associations (Altani, Protopapas, & Georgiou, 2017; Protopapas, Altani, & Georgiou, 2013b; but cf. Kuperman, van Dyke, & Henry, 2016).

By developing and elaborating this rationale, de Jong (2011; see also Rodríguez, van den Boer, Jiménez, & de Jong, 2015; van den Boer & de Jong, 2015) hypothesized that the relationship between RAN and discrete word reading could reveal the extent to which word reading processes rely on serial operations. Specifically, if children rely on a serial decoding strategy, then word reading should correlate more strongly with serial naming than with discrete naming irrespective of the format of the reading task. In contrast, if children read words by sight, then naming and reading of the same format (i.e., both serial or both discrete) should correlate more strongly than tasks of different format, because discrete naming and discrete reading both would reflect single-step intake of the individual stimuli, whereas serial naming and serial reading both would reflect sequential processing of successive stimuli (in addition to lexical access and other common visual, phonological, and articulatory processes involved in the processing of individual stimuli in both tasks). Indeed, de Jong (2011) found that the link between naming and reading was format specific among experienced readers, whereas serial RAN remained a stronger correlate of both single-word and word-list reading than discrete naming among novice readers. These findings were subsequently replicated by Protopapas et al. (2013a) in

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