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The Contribution of RAN Pause Time and Articulation Time to Reading Across

Languages: Evidence from a More Representative Sample of Children

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Abstract

We examined the relationship between rapid automatized naming (RAN) components – articulation time and pause time – and reading fluency across languages varying in orthographic consistency. Three hundred forty-seven Grade 4 children (82 Chinese-speaking Taiwanese children, 90 English-speaking Canadian children, 90 Greek-speaking Cypriot children, and 85 Finnish-speaking children) were assessed on RAN (Colors and Digits) and reading fluency (word reading efficiency and text reading speed). The results showed that articulation time accounted for more unique variance in reading in the alphabetic orthographies than in Chinese, and pause time for more unique variance in reading in Chinese than in alphabetic orthographies. If automaticity in RAN is manifested with a higher contribution of articulation time to reading fluency than pause time and with a strong relationship between articulation time and pause time, then our findings suggest that automaticity in RAN is reached earlier in alphabetic orthographies than in Chinese.

Keywords: rapid automatized naming, reading fluency, cross-linguistic, orthographic consistency

The Contribution of RAN Pause Time and Articulation Time to Reading Across

Languages: Evidence from a More Representative Sample of Children

Rapid automatized naming (RAN), defined as the ability to name as fast as possible highly familiar visual stimuli, such as digits, letters, colors, and objects, is a strong predictor of reading in all languages studied so far (e.g., *Finnish*: Lepola, Poskiparta, Laakkonen, & Niemi, 2005; *Greek*: Protopapas, Altani, & Georgiou, 2013; *German*: Moll, Fussenegger, Willburger, & Landerl, 2009; *Dutch*: de Jong & van der Leij, 1999; *English*: Parrila, Kirby, & McQuarrie, 2004; *Korean*: Cho & Chiu, in press; *Chinese*: Pan et al., 2011). In most previous studies, the score in RAN has been the total time it takes an individual to name the entire series of stimuli. However, researchers have argued that the total time fails to provide the precision needed to adequately determine the nature of RAN and its relation to reading, and proposed that the RAN time should be partitioned into its constituent components of articulation time and pause time (Georgiou, Parrila, & Kirby, 2006; Neuhaus, Foorman, Francis, & Carlson, 2001). Articulation time has been described as an index of response automaticity and pause time as an index of the automaticity in accessing and retrieving the phonological codes from long-term memory (Neuhaus et al., 2001). The purpose of this study was to examine the role of articulation time and pause time in reading fluency across four languages that were selected to represent different points along the orthographic consistency continuum (Chinese, English, Greek, and Finnish).

Previous studies conducted in English have shown that variance in RAN total time is primarily attributed to variability in pause time (e.g., Cobbold, Passenger, & Terrell, 2003; Neuhaus et al., 2001), that articulation time and pause time are only weakly correlated (e.g., Cobbold et al., 2003; Georgiou et al., 2006), and that pause time is driving the RAN-reading relationship (e.g., Cobbold et al., 2003; Neuhaus et al., 2001). More recent studies in Greek,

however, have shown that pause time and articulation time correlate with each other by Grade 2 (Georgiou, Papadopoulos, Fella, & Parrila, 2012) and that articulation time is an equally strong predictor of reading fluency as pause time by Grade 4 (Georgiou, Papadopoulos, & Kaizer, in press). These findings suggest that there may be differences across languages not only in the relationship between the components, but also in their contribution to reading.

To date, only one study has examined the contribution of RAN components to reading across languages (Chinese, English, and Greek) varying in orthographic consistency, but it included a small sample of Grade 4 children ($n = 40$ in each site). Georgiou, Parrila, and Liao (2008) found that the contribution of pause time decreased as orthographic consistency increased: pause time accounted for a larger amount of variance in reading in Chinese than in English or Greek. In contrast, the contribution of articulation time increased as orthographic consistency increased: articulation time accounted for a larger amount of variance in reading in Greek than in English or Chinese. We extend Georgiou et al.'s (2008) study in two directions: first, we assessed a larger sample of children and second, we included Finnish, which is more transparent than Greek and an ideal contrast to English and Chinese (the entropy values for Finnish, Greek, and English are .00, .19, and .83, respectively; see Protopapas & Vlachou, 2009; Ziegler et al., 2010).

Examining the contribution of articulation time and pause time to reading ability across languages varying in orthographic consistency allows us to test some interesting hypotheses. If alphanumeric RAN (letters and digits) becomes automatic by the age of 10 (around Grade 4; see Albuquerque & Simões, 2012; Georgiou & Stewart, 2013), we should observe a larger effect of articulation time in reading fluency than pause time and also a strong correlation between articulation time and pause time (see Georgiou et al., in press, for some preliminary evidence in

support of this hypothesis). In addition, given the reciprocal relationship between RAN and reading (Compton, 2003), the aforementioned relationships should be more evident in consistent orthographies (i.e., Finnish and Greek) than in inconsistent orthographies (English) because the feedback children receive from their head start in decoding helps them build distinct phonological representations of written words that are easy to access (e.g., Goswami, 2002). If children, irrespective of their reading ability, have distinct and easily accessible phonological representations, there will be very little variability in pause time and weaker correlations with reading. In Chinese, a morphosyllabic language in which the role of phonology in word reading is not as strong as in alphabetic orthographies (only 23-26% of the Chinese characters can be read accurately using the phonetic radical; Chung & Leung, 2008) the development of reading has a limited impact on RAN (REFERENCE) and therefore, by Grade 4, pause time should continue to be the strongest predictor of reading. This would mimic the relationships found between RAN components and reading in alphabetic orthographies before children learn to read (Georgiou, Tziraki, Manolitsis, & Fella, 2013; Lervåg & Hulme, 2009). Likewise, because non-alphanumeric RAN (colors and objects) does not reach automaticity before the age of 16 (Albuquerque & Simões, 2012) and is less influenced by reading ability (Compton, 2003) pause time should continue to be a stronger predictor of reading than articulation time and this pattern should hold across languages.

Method

Participants

Eighty-two Chinese-speaking Taiwanese children (46 girls and 36 boys, mean age = 123.09 months, SD = 3.21), 90 English-speaking Canadian children (50 girls and 40 boys, mean age = 116.48 months, SD = 4.26), 90 Greek-speaking Cypriot children (52 girls and 38 boys,

mean age = 116.70 months, SD = 4.38), and 85 Finnish children (49 girls and 36 boys, mean age = 131.06 months, SD = 4.12) participated in the study. All children attended Grade 4 classrooms and were recruited on a voluntary basis, following permission from their parents. In addition, all children were native speakers of their language and had no documented sensory or behavioural difficulties. General cognitive ability, measured with Block Design from WISC III (Wechsler, 1991), was within average range (*Chinese*: Mean standard score = 10.60, SD = 2.49; *English*: Mean standard score = 10.88, SD = 3.58; *Greek*: Mean standard score = 10.64, SD = 2.62 and *Finnish*: Mean standard score = 10.07, SD = 2.96).

Materials

Rapid Automatized Naming (RAN). RAN was assessed with Color Naming and Digit Naming. Both tasks were adopted from RAN/RAS test battery (Wolf & Denckla, 2005) and required children to state as quickly as possible the names of five colors (blue, black, green, red, yellow) or digits (2, 7, 4, 9, 5) arranged semi-randomly in five rows of ten. Prior to beginning the timed naming, each child was asked to name the colors or digits in a practice trial to ensure familiarity. Only few naming errors occurred (the mean was less than 1 in each task and language) and they were not considered further. All performances on both RAN tasks were recorded to allow the analyses described below. Wolf and Denckla (2005) reported test-retest reliability across ages for Color and Digit Naming to be .90 and .92, respectively. The correlations between the two tasks in our sample were .62 in Chinese, .70 in English, .71 in Greek, and .55 in Finnish.

The names of colors in Chinese, Greek, and Finnish are [*lan*]2, [*mble*], and [*sininen*] for blue, [*hai*]1, [*mavro*], and [*musta*] for black, [*lui*]4, [*prasino*], and [*vihreä*] for green, [*hong*]2, [*kokino*], and [*punainen*] for red, and [*huang*]2, [*kitrino*], and [*keltainen*] for yellow. The mean

number of phonemes for the colors was 3.6 in Chinese, 3.6 in English, 5.8 in Greek, and 7.0 in Finnish. The names of digits in Chinese, Greek, and Finnish are [*er*]4, [*dio*], and [*kaksi*] for two, [*qi*]1, [*epta*], and [*seitsemän*] for seven, [*si*]4, [*tesera*], and [*neljä*] for four, [*jiu*]3, [*eŋa*], and [*yhdeksän*] for nine, and [*wu*]3, [*pede*], and [*viisi*] for five. The mean number of phonemes for the digits was 2.2 in Chinese, 3.6 in English, 4.8 in Greek, and 5.8 in Finnish.

Reading ability. Two measures of reading fluency were administered: word reading efficiency and text reading speed. Comparable measures of both either exist or could be developed across languages. Reading accuracy was also assessed, but it was at ceiling in Finnish and Greek and it is not considered further. Word reading efficiency was assessed in English with the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999). An adaptation of this task was used in Greek and Finnish. The score was the number of words read correctly in 45 seconds (max = 104). Torgesen et al. (1999) reported test-retest reliability of .95 for ages six to nine. One-Minute Reading (Ho, Chan, Tsang, & Lee, 2000) was used to assess word reading efficiency in Chinese. Children read as many of the 90 simple Chinese two-character words as possible in one minute. Ho et al. (2000) reported split-half reliability of .99 for grade 4.

Gray Oral Reading Test (Wiederholt & Bryant, 2001) was used to assess text reading speed in English. The participants were asked to read as fast and as accurately as possible two short stories. The stories were selected so that one would be well within the reading ability of almost all children, and one a bit more challenging; all participants read the same two stories. Story 1 consisted of 41 words and Story 2 of 106 words. A rate score was calculated by dividing the number of correctly read words in each story by the total time to read the story. A participant's score was the average of the two rate scores. Wiederholt and Bryant (2001) reported

test-retest reliability for GORT to be .93. The two stories were translated and back translated in the other three languages following international standards (van de Vijver & Hambleton, 1996). The length of the stories in the other languages was 31 and 92 words in Greek, 28 and 77 in Finnish, and 61 and 161 in Chinese, respectively. The correlation between the reading times of the two stories in our sample was .64 in Chinese, .77 in English, .88 in Greek, and .62 in Finnish.

Procedure

All participants were examined in April/May (approximately eight/nine months after the beginning of the school year) in each of the countries. They were tested individually in their schools during school hours by trained experimenters that followed the same testing protocol. Testing was completed in one 40-minute session and the tests were administered in fixed order within and across languages.

Manipulation of Sound Files

The sound files of each participant on both RAN tasks were analyzed using GoldWave v.4.26 (GoldWave Inc. 2002). Data extraction was completed following the procedure described in Georgiou et al. (2006). Articulation time represents the mean of those articulation times that were correctly verbalized and were not preceded by a skipped stimulus (max = 50). Pause time represents the mean of those pause times that occurred between two correctly articulated stimuli (max = 49). Both components were measured in milliseconds.

<div align="center">Results</div>

Preliminary Data Analysis

Table 1 presents the descriptive statistics for all the measures and Table 2 the correlations between RAN components and reading fluency. In Color Naming, pause time correlated higher with both reading measures than articulation time. In contrast, in Digit Naming, articulation time

correlated higher with reading fluency than pause time (with the exception of Chinese). In order to examine if the correlations between the RAN components and the reading measures differed significantly across languages, a z test was performed using Fischer's r to z transformations (Glass & Hopkins, 1984). Color Naming articulation time in Finnish correlated more strongly with word reading efficiency ($z = 2.25$; $p < .05$) and text reading speed ($z = 2.05$; $p < .05$) than articulation time in Chinese. Finally, Digit Naming articulation time in Finnish correlated more strongly with word reading efficiency than articulation time in Chinese ($z = 2.36$; $p < .05$).

Commonality Analyses with RAN Components and Reading Outcomes

Because articulation times and pause times correlated significantly with each other (rs ranged from .16 to .37 in Chinese, .35 to .62 in English, .40 to .51 in Greek, and .51 to .65 in Finnish), we performed commonality analyses (Pedhazur, 1982) to examine their unique (2) and shared (1) contributions to reading fluency across languages. The top half of Table 3 presents the results with the RAN Colors components and the bottom half of Table 3 presents the results with the RAN Digits components. The sum values at the last row of each half of Table 3 are equal to the total variance explained by the three commonality components.

Table 3 indicates that there were some similarities as well as some differences in the importance of the two RAN components across languages. First, with the exception of Chinese, the component shared by articulation time and pause time accounted for a sizeable proportion of the explained reading variance. Specifically, the proportion of variance accounted for by the shared component ranged from 42% (100 * (.1390/.3313)) to 50% (100 * (.1168/.2351)) in RAN Colors and from 48% to 60% in RAN Digits.

Second, articulation time was more important in alphabetic orthographies than in Chinese. In RAN Colors, articulation time accounted for 12% of the explained variance in

Chinese word reading efficiency, compared to 17% in English, 20% in Greek, and 21% in Finnish. In RAN Digits, articulation time accounted for 10% of the explained variance in Chinese word reading efficiency, compared to 28% in English, 40% in Greek, and 33% in Finnish. Similar proportions were found when text reading speed was the dependent variable.

Finally, pause time was clearly more important in Chinese than in the other three languages. RAN Colors pause time accounted for 80% of the explained variance in Chinese word reading efficiency, compared to 41% in English, 32% in Greek, and 29% in Finnish. In RAN Digits, pause time accounted for 61% of the explained variance in word reading efficiency in Chinese, 14% in English, 12% in Greek, and 6% in Finnish. Similar proportions were found when text reading speed was the dependent variable.

Discussion

The purpose of this cross-linguistic study was to examine the contribution of articulation time and pause time to reading fluency across four languages varying in orthographic consistency. We found that the differences in the contribution of RAN components to reading were most obvious in the Chinese (a non-alphabetic orthography) - Finnish (the most consistent alphabetic orthography) comparison. The results for English and Greek were close to those observed in Finnish. Although the results in Greek could be expected given the closeness of Greek to Finnish in orthographic transparency, the results in English were more surprising given its considerably higher entropy value. A possible explanation may be that our English-speaking Canadian children were reading beyond their grade level (their mean reading age according to the manual in TOWRE was 5.2) and for this reason were more similar in reading ability to Finnish or Greek children.

The results of the commonality analyses revealed first that the component shared by articulation time and pause time accounted for roughly half of RAN's predictive value in reading fluency in the alphabetic orthographies. This component may partly reflect speed of processing that is important not only for the processing of information within a sub-process (e.g., within articulation or phonological encoding), but also for the integration of information across sub-processes (e.g., from articulation to phonological encoding). This explanation is in line with the argument put forward by Bowey, McGuigan, and Ruschena (2005) that, at different stages of reading development, part of the RAN-reading relationship is mediated by processing speed. However, processing speed cannot be the only explanation. First, it cannot explain why the amount of predictive variance shared between articulation time and pause time is systematically higher in RAN Digits than in RAN Colors. Second, it is hard to explain why processing speed would be less important for reading in Chinese than in alphabetic orthographies. Beyond speed of processing, the shared component may reflect the degree of overlap in the processes underlying pause time and articulation time. Advanced readers likely access and retrieve the phonological codes of subsequent items during the articulation of preceding items. Two pieces of evidence support this explanation: First, the correlations between articulation time and pause time are non-significant during the early stages of reading development (e.g., Cobbold et al., 2003; Neuhaus et al., 2001), but become strong as children master reading (e.g., Clarke et al., 2005; Georgiou et al., 2012). Second, eye-movement studies have shown that readers take advantage of the serial format of RAN tasks to process parafoveal information (e.g., Pan, Yan, Laubrock, Shu, & Kliegl, 2013; Yan, Pan, Laubrock, Kliegl, & Shu, 2013).

We argue here that the size of this shared component may be an index of automaticity in RAN. The more automatic RAN is (which translates to shorter and fewer pauses), the greater the

overlap between articulation time and pause time will be. A look at the number of pauses in our study supports this argument. Specifically, the mean number of pauses in RAN Digits in Chinese was 39.35, in English 31.55, in Greek 30.10, and in Finnish 28.06. The corresponding number of pauses in RAN Colors was 42.88 in Chinese, 40.11 in English, 35.75 in Greek, and 33.70 in Finnish.

An important limitation of our study should be mentioned. Because the names of Finnish and Greek colors and digits are longer than in English or Chinese it is possible that these differences account for the stronger effects of articulation time to reading observed in these languages (longer articulations allow more time to process the next stimulus). Ideally, we should have included languages varying in transparency, but not in word length. However, word length cannot be the only explanation for the increased role of articulation time because color names were longer than digit names in Finnish and Greek, but Color Naming pause time predicted more strongly reading fluency in both languages. Certainly, future studies should attempt to match the length of the stimuli across languages to eliminate this explanation.

To conclude, within each language, pause time explained more variance than articulation time in Color Naming, while articulation time explained more variance than pause time in Digit Naming (except in Chinese). Across languages, articulation time accounted for more unique variance in the alphabetic orthographies than in Chinese, and pause time for more unique variance in Chinese than in alphabetic orthographies. The findings suggest that automaticity in RAN (particularly alphanumeric) is reached earlier in alphabetic orthographies than in Chinese.

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Table 1

Descriptive Statistics of the Tasks Used in Each Language

	Chinese n = 82		English n = 90		Greek n = 90		Finnish n = 85	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
RAN-Colors								
Total Time[1]	49.52	10.72	43.52	10.53	43.91	8.47	44.98	11.35
Articulation Time[2]	501.28	107.11	443.10	73.47	577.42	84.71	608.59	73.81
Pause Time[2]	476.69	197.72	399.77	177.61	223.51	109.72	216.47	124.48
RAN-Digits								
Total Time[1]	25.05	6.03	27.58	6.71	26.16	5.32	32.82	7.91
Articulation Time[2]	343.25	60.67	391.19	62.13	396.19	69.94	480.50	85.60
Pause Time[2]	160.48	98.65	152.89	87.45	109.07	52.58	136.37	83.83
Word Reading Efficiency	53.94	11.16	70.59	8.99	58.91	12.82	71.89	10.41
Text Reading Speed[3]	2.68	.59	2.68	.68	2.22	.67	2.52	.50

Note. [1.] Measured in seconds. [2.] Measured in milliseconds. [3.] Number of words per second.

Table 2

Correlations between RAN and Reading Fluency in Chinese, English, Greek, and Finnish

	Chinese		English		Greek		Finnish	
	WRE	TRS	WRE	TRS	WRE	TRS	WRE	TRS
Colors AT	-.18	-.10	-.39	-.27	-.45	-.40	-.49	-.40
Colors PT	-.35	-.29	-.45	-.36	-.52	-.48	-.51	-.44
Digits AT	-.31	-.32	-.54	-.49	-.59	-.51	-.60	-.38
Digits PT	-.54	-.48	-.53	-.37	-.49	-.44	-.51	-.32

Note. Correlations between .27 and .32 are significant at the .05 level and correlations higher than .32 are significant at the .01 level. AT = Articulation Time; PT = Pause Time; WRE = Word Reading Efficiency; TRS = Text Reading Speed.

Table 3

Unique and Common Contributions of RAN Color Components on Reading Fluency Across Languages

	Word Reading Efficiency				Text Reading Speed			
	Chinese	English	Greek	Finnish	Chinese	English	Greek	Finnish
	Color Naming							
Unique Contributions								
1. Articulation Time	.0151 (12)	.0565 (17)	.0682 (20)	.0722 (21)	.0098 (10)	.0262 (13)	.0517 (18)	.0458 (19)
2. Pause Time	.0995 (80)	.1358 (41)	.1103 (32)	.0961 (29)	.0690 (70)	.0837 (43)	.1014 (35)	.0725 (31)
Common Contributions								
Common to 1 & 2	.0103 (08)	.1390 (42)	.1644 (48)	.1679 (50)	.0201 (20)	.0844 (43)	.1319 (47)	.1168 (50)
Sum	.1249	.3313	.3439	.3362	.0989	.1943	.2835	.2351
	Digit Naming							
Unique Contributions								
1. Articulation Time	.0383 (10)	.1009 (28)	.1600 (40)	.1279 (33)	.0490 (15)	.0711 (29)	.1542 (37)	.0536 (34)
2. Pause Time	.2328 (61)	.0510 (14)	.0469 (12)	.0236 (06)	.1789 (54)	.0409 (16)	.0423 (10)	.0085 (05)
Common Contributions								
Common to 1 & 2	.1082 (29)	.2102 (58)	.1900 (48)	.2332 (60)	.1056 (31)	.1356 (55)	.2191 (53)	.0932 (60)
Sum	.3793	.3621	.3969	.3847	.3335	.2476	.4157	.1553

Note. In parenthesis we report the percentage of RAN's predictive value in reading that is accounted for by each commonality component.