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Early prediction of reading development in Japanese hiragana and kanji: a longitudinal study from kindergarten to grade 1

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Abstract
We examined the cognitive predictors of early word reading skills in Japanese syllabic Hiragana and morphographic Kanji. Eighty-three Japanese kindergarten children (*M* age = 75.6 months, *SD* = 3.4) were assessed on nonverbal IQ, vocabulary, phonological awareness, rapid automatized naming (RAN), phonological memory, morphological awareness, and visual discrimination at the end of kindergarten (T1). Their word reading fluency in Hiragana was assessed at T1 and reassessed in Grade 1 (T2), and their reading accuracy in Kanji was assessed at T2. Results of path analysis showed that phonological awareness, RAN, phonological memory, and visual discrimination were associated with Hiragana word reading fluency at T1, whereas morphological awareness uniquely predicted Hiragana word reading fluency at T2. Additionally, RAN, morphological awareness, vocabulary, and visual discrimination, but not Hiragana reading accuracy, uniquely predicted Kanji reading at T2. The findings provided evidence that RAN, morphological awareness, and visual discrimination play important roles in early reading development across the two contrastive scripts.

Keywords Early reading development · Morphological awareness · Phonological awareness · Rapid automatized naming (RAN) · Visual discrimination

Introduction

A growing number of studies have examined the cognitive predictors of early reading development across languages and have provided evidence for both universal and language-specific cognitive predictors of early reading skills (e.g., Furnes et al.,

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2019; Landerl et al., 2019). However, the majority of cross-orthographic studies have been conducted in alphabetic orthographies (e.g., Georgiou et al., 2008, 2012; Ziegler et al., 2010), whereas studies in non-alphabetic orthographies remain relatively rare except for studies in Chinese (e.g., McBride-Chang & Kail, 2002; McBride-Chang et al., 2005). Thus, the present study examined the cognitive predictors of early word reading skills in Japanese, which is characterized by the combined use of two contrastive scripts (syllabic Hiragana and morphographic Kanji) in a 1 year longitudinal sample of Japanese kindergarteners.

Hiragana and kanji in Japanese

Hiragana is a consistent syllabic/moraic orthography, where each character basically corresponds only to one syllable/mora, whereas Kanji is an inconsistent morphographic orthography, where each character represents morphemic units and sounds dependent on the context (Iwata, 1984; Koda, 2017). For example, the Kanji character 歌 is read as /uta/ 'song' when presented by itself but is frequently read as /ka/ when it forms part of compound Kanji words (e.g., 歌手 /ka-shu/ 'singer', 国歌 /k:o-ka/ 'national anthem'). Another notable difference between the two scripts is the level of visual complexity, which is substantially higher for Kanji than Hiragana (e.g., 綴 'spelling' comprises 14 strokes; see Chang et al., 2018). Hiragana is taught first during formal reading instruction in school because of its simplicity (Ministry of Education, Culture, Sports, Science and Technology, 2017). The majority of children master Hiragana reading quickly within the first few months of grade 1. The focus of reading instruction then shifts to teaching kanji in the first few months of grade 1.

Cognitive predictors of early reading skills in hiragana and kanji

The present study focuses on a wide range of theoretically essential cognitive predictors of early reading skills: phonological awareness, rapid automatized naming (RAN), phonological memory, morphological awareness, and visual discrimination. These cognitive predictors were selected based on the findings of previous studies across diverse writing systems (e.g., Furnes et al., 2019; Hulme et al., 2019; Landerl et al., 2019; Wang & McBride, 2016), including Japanese (Inomata et al., 2013; Inoue et al., 2017, 2019; Kakihana et al., 2009; Kobayashi et al., 2005; Koyama et al., 2008; Muroya et al., 2017; Ogino et al., 2017). Previous meta-analytic studies have shown that (a) among the phonological processing skills (phonological awareness, phonological memory, and RAN; see Torgesen et al., 1994), phonological awareness and RAN are universal predictors of reading development, and phonological memory may be somewhat associated with reading skills (Kastamoniti et al., 2018; Melby-Lervåg et al., 2012; Song et al., 2016), (b) morphological awareness plays a key role in reading development in both alphabetic and non-alphabetic orthographies (Ruan et al., 2018), and (c) visual discrimination may be relatively

more important for learning an orthography that uses visually complex scripts, such as Chinese, particularly during the early reading development (Yang et al., 2013).

Several studies on Japanese have directly compared the effects of the cognitive factors on word reading between Hiragana and Kanji but have produced mixed findings (e.g., Inoue et al., 2017; Koyama et al., 2008; Muroya et al., 2017; Ogino et al., 2017). For example, Ogino et al. (2017) conducted a longitudinal study with a sample of Japanese kindergarteners and examined the contribution of cognitive skills (phonological awareness, RAN, phonological memory, and visual memory) to Hiragana reading fluency and Kanji reading accuracy. The results showed that although RAN in Kindergarten predicted Hiragana reading fluency in Grade 1, phonological awareness in kindergarten predicted Kanji reading accuracy in Grade 2. Moreover, Inoue et al. (2017) investigated the contribution of various cognitive skills (phonological awareness, RAN, phonological memory, orthographic knowledge, and morphological awareness) to Hiragana reading fluency and Kanji reading accuracy and fluency. They found that phonological awareness, orthographic knowledge, and morphological awareness were uniquely associated with Hiragana reading accuracy in Grade 1, whereas orthographic knowledge and morphological awareness uniquely predicted later Kanji reading accuracy. In summary, the findings of the abovementioned studies have suggested that Japanese children learning two contrasting orthographic systems may develop partially independent cognitive bases for reading skill acquisition of the two scripts.

However, the existing studies on Japanese have two important limitations. First, a paucity exists in longitudinal studies on Japanese, which covers the transition period from kindergarten to grade 1. To the best of our knowledge, only one study (Ogino et al., 2017) has examined the cognitive predictors of early reading development in Hiragana and Kanji in a sample of children followed from kindergarten to grade 2. Ogino et al. (2017) excluded measures on morphological awareness or visual discrimination, both of which have been demonstrated to play important roles in reading development in non-alphabetic orthographies such as Chinese (e.g., McBride-Chang et al., 2002; Wang & McBride, 2016). Therefore, their possible effects on early reading development in Japanese remain unknown. Japanese children learn basic Hiragana characters even before the commencement of formal reading instruction in grade 1 (e.g., Ota et al., 2018). Thus, examining the development of early reading skills during this period is important. Second, studies on the relationship between visual discrimination and early reading development in Japanese have been rare (for an exception, see Koyama et al., 2008). Indeed, studies that compared the effects of visual discrimination on reading development in the two scripts of Japanese in kindergarteners have been lacking. This aspect is theoretically important because syllabic Hiragana and morphographic Kanji are contrastively different in terms of graphic complexities (Chang et al., 2018).

The present study

The present study is longitudinal in nature and examines the role of phonological awareness, RAN, phonological memory, morphological awareness, and visual discrimination in predicting word reading skills in syllabic Hiragana and morphographic Kanji. The sample comprises Japanese children followed from Kindergarten to Grade 1. Based on the findings of the existing studies in Japanese and other abovementioned, the present study expects that the relative importance of the cognitive predictors of early reading development would differ between the two scripts. Specifically, we hypothesize that:

(1) RAN (Inoue et al., 2017; Kobayashi et al., 2005), phonological awareness (Inomata et al., 2013; Kobayashi et al., 2005), phonological memory (Inoue et al., 2020; Kakihana et al., 2009), and morphological awareness (Inoue et al., 2017; Muroya et al., 2017) in Kindergarten would predict Hiragana reading fluency in Grade 1, and
(2) Visual discrimination (Hulme et al., 2019; Li et al., 2012; Luo et al., 2013), RAN (Georgiou et al., 2017; Wang & McBride-Chang, 2016), morphological awareness (Inoue et al., 2017; Muroya et al., 2017), and vocabulary (Inoue et al., 2017; Uno et al., 2009) in Kindergarten would predict Kanji reading accuracy in Grade 1.

Method

Participants

We approached four kindergartens in [city's name removed for review], Japan. A total of 83 third-year kindergarteners (girls = 37, boys = 46; mean age = 75.6 months, *SD* = 3.4) were given parental permission to participate in this study. The kindergartens participated in the study followed the national standard curriculum, which is set by the Ministry of Education. None of the kindergartens conducted formal teaching of Hiragana. The children were followed from the end of kindergarten (Time 1 [T1]) to the middle of grade 1 (Time 2 [T2]). Of this initial sample, 79 participants (girls = 37, boys = 42; mean age = 83.7, *SD* = 3.5) were reassessed at T2. The decrease was due to attrition attributed to children either moving out of the study area or absent from school. All children were native Japanese speakers. None was identified to be with intellectual or sensory deficits.

Measures

Nonverbal cognitive ability

Matrix reasoning from the Japanese adaptation of the Wechsler intelligence scale for children-fourth edition (WISC-IV; Japanese WISC-IV Publication Committee, 2010) was used to assess nonverbal cognitive ability. To reduce testing time and fatigue among the children, we extracted nine items with reference to the norm sample of Japanese 6–7 year old children. Each correct answer earned one point for a maximum score of 9.

Vocabulary

Vocabulary from WISC-IV (Japanese WISC-IV Publication Committee, 2010) was used to assess children's vocabulary knowledge. Five items were extracted from the original 35 items based on the data from the norm sample (Japanese WISC-IV Publication Committee, 2010). Each item was rated from 0–2 points based on the manual with a possible maximum score of 10.

Phonological awareness

The elision task was used to assess phonological awareness. The task was adapted from Inoue et al. (2017) and modified to suit the objective of the present study based on the age of the sample. From the original pool of 24 items, we extracted seven items that had different difficulty levels. Children were required to repeat a three-mora word and said the word without saying the middle mora (e.g., /haNko/ 'stamp' without the /N/ is /hako/ 'box'). The task comprised seven items. Before testing two practice items were administered first to ensure that children understood the task. The task was discontinued after four consecutive errors. Each correct answer earned one point for a maximum score of 7.

Phonological memory

The nonword repetition task was used to assess phonological memory. With reference to Inomata et al. (2013), children were required to repeat a five- to nine-mora string (i.e., nonwords) as correctly as possible. The nonwords were arranged in terms of increasing level of difficulty (i.e., the number of morae of the items gradually increased). We used seven items developed for this study. Testing was discontinued after four consecutive errors. Each correct answer earned one point for a maximum score of 7.

Rapid automatized naming (RAN)

In the digits naming task, children were required to name five recurring digits (i.e., 2, 3, 5, 6, and 8, which are pronounced as /ni/, /san/, /go/, /roku/, and /hachi/, respectively) as fast as possible. The digits were arranged in four rows of five items. Before

testing, the children named the stimuli in a practice trial to ensure familiarity. A child's score was the time to finish naming the digits.

Morphological awareness

The word analogy task (Muroya et al., 2017) was used to assess morphological awareness. Children were presented with a word immediately after a sample pair of two words and asked to produce the missing word in the target pair (e.g., /taberu/ 'eat': /tabeta/ 'ate':: /nomu/ 'drink': [/nonda/ 'drunk']). The task comprised five items that involved derivational changes with reference to Muroya et al. (2017). Of the five items, two had different phonological changes in the two word pairs (e.g., /hanashi/ 'story': /hanasu/ 'talk':: /asobi/ 'game': [/asobu/ 'play']); the other three items had the same phonological changes in the first and second pairs (e.g., /kirei/ 'clean': /kireini/ 'cleanly':: /shizuka/ 'quiet':: ____ [/shizukani/ 'quietly']). Three practice items were administered before testing to ensure that the children understood the task. The task was discontinued after three consecutive errors. Each correct answer earned one point for a maximum score of 5.

Visual discrimination

The figure matching task was adapted from Okumura and Miura (2014). Children were required to determine the target figure from four comparison figures as fast as possible. Five figures were lined up horizontally: Each target figure was located at the leftmost side, whereas the four comparison figures were arranged 2 cm away from the target. Numbers (i.e., 1, 2, 3, and 4) were attached below each comparison figure. The children answered by stating the number or by pointing at the comparison figure. The time limit was set to 60 s, and the total number of correct answers within the time limit was recorded. The task comprised 24 items, and six items were arranged on one page. Each correct answer earned one point for a maximum score of 24.

Hiragana reading accuracy

The Hiragana nonword decoding task was used, which comprised 15 four-character Hiragana nonwords. The nonwords included 46 basic Hiragana characters with four voiced, one semi-voiced, and five special sounds, and they were arranged in terms of increasing level of difficulty (i.e., the test started with nonwords consisting of only basic Hiragana characters). Children were required to read the nonwords as accurately as possible. The total number of correct answers was considered the score with a maximum score of 15.

Hiragana reading fluency

The Hiragana word reading fluency task (Inoue et al., 2020) was used. The task comprised 104 four–character Hiragana words taken from grade 1 textbooks. The list of words was divided into four columns with 20 or 21 words arranged per column. To

ensure familiarity, a practice trial that required reading an eight-word list was conducted before testing. Children were asked to read the list of 104 Hiragana words as quickly as possible. The score was the number of words correctly read within 45 s with a maximum score of 104.

Kanji reading accuracy

The Kanji reading task was adopted from Inoue et al. (2017) and used to assess Kanji reading accuracy. The task comprised 50 Kanji characters arranged according to the increasing level of difficulty. Children were required to read the Kanji characters as accurately as possible. The task was discontinued after four consecutive errors. The total number of correct answers was a child's score with a maximum score of 50. We did not assess Kanji reading fluency in Grade 1 because children had just started learning Kanji, and therefore, we thought that reading accuracy would be a more valid measure of Kanji reading than reading fluency (see Juul et al., 2014).

Procedure

Children were assessed in January/February of the third year of kindergarten (T1) and reassessed in September/October in grade 1 (T2). They were assessed for nonverbal cognitive ability, vocabulary, phonological awareness, phonological memory, RAN, morphological awareness, visual discrimination, and Hiragana reading accuracy and fluency at T1. Moreover, they were assessed for Hiragana word reading fluency and Kanji reading accuracy at T2. We expected that the majority of children would be unable to read Kanji characters in Kindergarten. Hence, Kanji reading accuracy was not assessed at T1. The children were tested individually in their

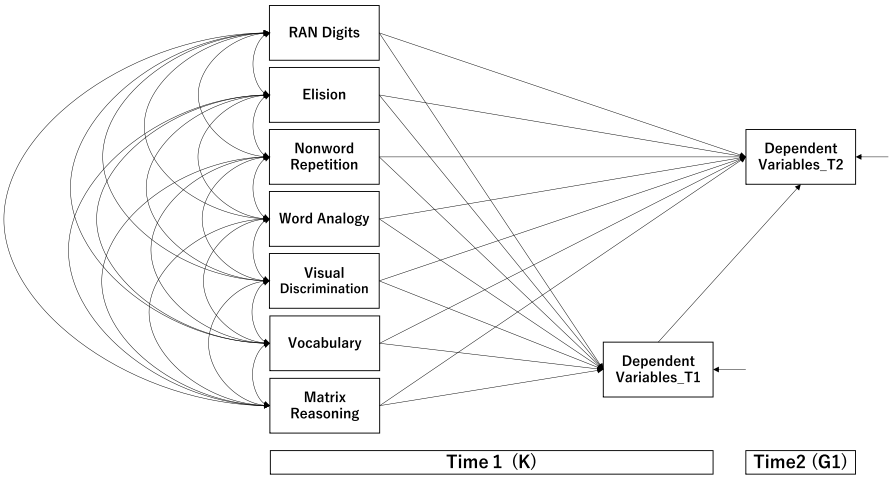

Fig. 1 Baseline model of relationships between predictors and outcome measures

kindergartens and schools during school hours by trained experimenters. When this setting was unavailable (e.g., absence from school), children were tested in a testing room in [university's name removed for review]. The testing time lasted for 30 min and 20 min at T1 and T2, respectively.

Statistical analysis

Path analyses using SPSS Amos 25.0 was performed to examine the concurrent and longitudinal effects of different cognitive predictors on word reading skills. The analyses were conducted in two steps. First, separate baseline models (Fig. 1) were constructed for Hiragana reading fluency and Kanji reading accuracy. Hiragana reading skills at T1 were used as autoregressors of reading skills at T2 (for a similar approach, see Inoue et al., 2017). The control variable in the models was the nonverbal cognitive ability of the children. Conversely, age was excluded from the models because it was not correlated with either Hiragana or Kanji reading (see Table 2). Second, nonsignificant correlation and regression paths were eliminated one at a time until all paths that remain in the models were significant to construct parsimonious models. The Full information maximum likelihood estimation (FIML) was used to address missing data. To evaluate model fit, the chi-square value and three fit indexes were used, namely, the comparative fit index (CFI), the Tucker-Lewis index (TLI), and the Root-mean-square error of approximation (RMSEA). Nonsignificant chi-square values, CFI and TLI values above 0.95, and RMSEA values below or at 0.06 indicate a good model fit (Kline, 2015).

Table 1 Descriptive statistics for the cognitive and reading measures

Measure (max)	*M*	*SD*	Min	Max
Time 1 (end of Kindergarten)				
Age in months	75.6	3.4	70	83
RAN digits	13.4	3.9	8.8	30.3
Elision (7)	4.0	2.5	0	7
Nonword repetition (7)	3.2	1.8	0	7
Vocabulary (10)	4.5	2.4	0	10
Word analogy (5)	1.9	1.5	0	7
Matrix reasoning (9)	5.1	1.8	1	9
Visual discrimination (24)	8.7	2.2	3	14
Word reading fluency in Hiragana (104)	27.7	14.3	2	69
Nonword reading accuracy in Hiragana (15)	12.0	3.1	0	15
Time 2 (middle of Grade 1)				
Age in months	83.7	3.5	70	83
Word reading fluency in Hiragana (104)	40.5	15.1	2	75
Reading accuracy in Kanji (50)	8.5	8.9	0	45

Table 2 Correlations among the cognitive and reading fluency measures

Measure	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	–	–	–	–	–	–	–	–	–	–	–	–
2. RAN	-.29**	–	–	–	–	–	–	–	–	–	–	–
3. Elision	.14	-.43**	–	–	–	–	–	–	–	–	–	–
4. Nonword repetition	.03	-.18	.31**	–	–	–	–	–	–	–	–	–
5. Word analogy	.22*	-.20	.32**	.22*	–	–	–	–	–	–	–	–
6. Visual discrimination	.20	-.29**	.31**	.16	.24*	–	–	–	–	–	–	–
7. Vocabulary	.06	-.24*	.33**	.44**	.09	.20	–	–	–	–	–	–
8. Matrix reasoning	-.07	.02	.17	.13	.24*	.08	.06	–	–	–	–	–
9. T1 HNWRA	.06	-.40**	.37**	.22**	-.02	.12	.22*	-.08	–	–	–	–
10. T1 HWRF	.07	-.48**	.43**	.31**	.35**	.38**	.33**	-.05	.46**	–	–	–
11. T2 HWRF	.10	-.50**	.49**	.35**	.35**	.37**	.32**	.00	.37**	.93**	–	–
12. T2 KRA	.03	-.50**	.41**	.26*	.38**	.53**	.31**	.02	.22*	.76**	.78**	–

Note. T = time; HNWRA = Hiragana nonword reading accuracy; HWRF = Hiragana word reading fluency; KRA = Kanji reading accuracy.

*$p < .05$; **$p < .01$

Results

Preliminary data analysis

Table 1 displays the descriptive statistics for all measures used. The distributional properties of the variables indicated that RAN and Kanji reading accuracy were positively skewed at both time points. Therefore, the square root transformation was conducted to improve the distribution. Alternatively, Hiragana reading accuracy at T1 was negatively skewed. Hence, the reflect and square root transformation was performed. The reflected scores were multiplied by −1 to correct for direction. Additionally, outliers on several measures in each sample (defined as more than 2.5 *SD* above/below the mean) were winsorized to the next non-outliers' score of ± 1 to reduce their potential effects on the results (Tabachnick & Fidell, 2012). The transformed scores were used in further analyses.

Predictors of hiragana reading fluency and kanji reading accuracy

Table 2 presents the correlations between all variables, and Fig. 2 depicts the final model for Hiragana reading fluency. The model fit the data well (χ^2 [20] = 21.84, $p = 0.35$, CFI = 0.99, TLI = 0.98, RMSEA = 0.03, 90%CI [0.00, 0.10]) and accounted for a moderate proportion of the variance in "Hiragana reading fluency" at T1 ($R^2 = 0.47$) and a large proportion of the variance in "Hiragana reading fluency" at T2 ($R^2 = 0.83$). The results demonstrated that RAN (β = 0.41), elision (β = 0.19), nonword repetition (β = 0.23), and visual discrimination (β = 0.20) were all uniquely associated with Hiragana reading fluency at T1. Additionally,

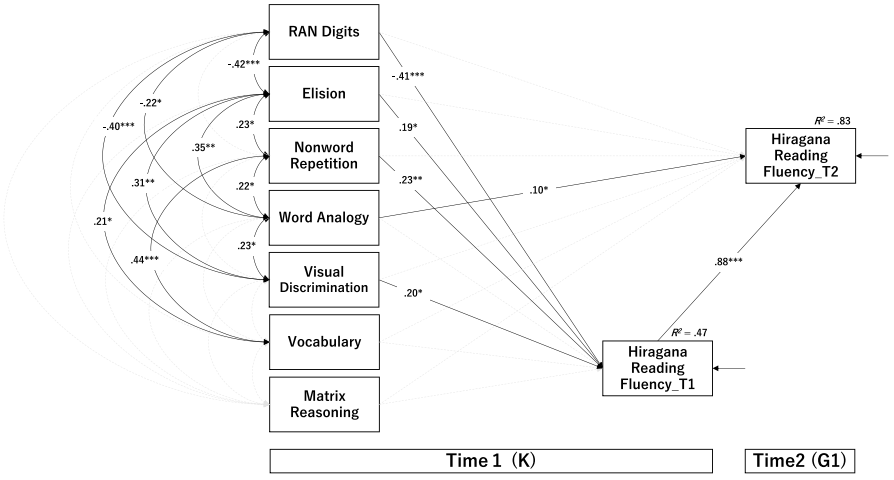

Fig. 2 Model of hiragana reading fluency: *Note*. Significant correlation and regression paths are drawn as solid lines, whereas nonsignificant paths are depicted as gray dotted lines *$p < .05$; **$p < .01$; ***$p < .001$

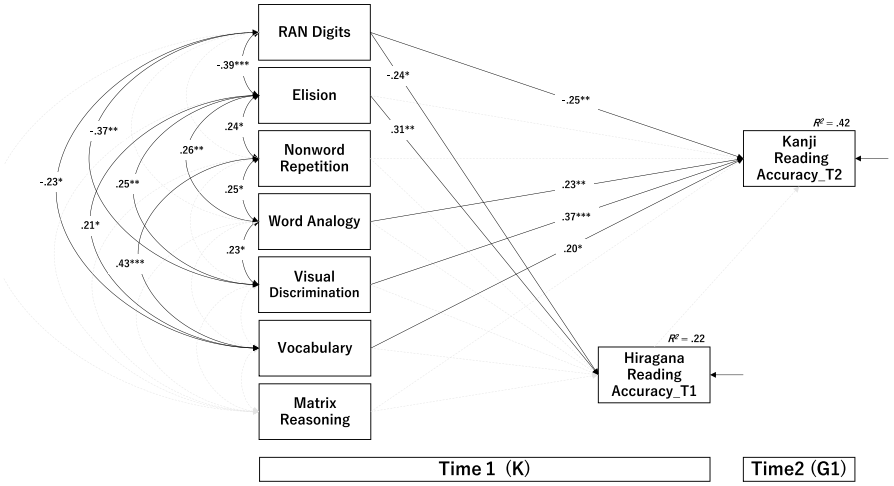

Fig. 3 Model of kanji reading accuracy: *Note.* Significant correlation and regression paths are drawn as solid lines, whereas nonsignificant paths are depicted as gray dotted lines $*p < .05$; $**p < .01$; $***p < .001$

word analogy predicted Hiragana reading fluency at T2 (β = 0.10) even after controlling for the strong effect of Hiragana reading fluency at T1 (β = 0.88).

Figure 3 illustrates the final model for Kanji reading accuracy. The model fit was excellent (χ^2 [19] = 18.26, $p = 0.51$, CFI = 1.00, TLI = 1.00, RMSEA = 0.00, 90%CI [0.00, 0.09]). The model accounted for a small proportion of variance in "Hiragana reading accuracy" at T1 ($R^2 = 0.22$) and a moderate proportion of the variance in "Kanji reading accuracy" at T2 ($R^2 = 0.42$). The results showed that RAN (β = -0.24) and elision (β = 0.31) were associated with Hiragana reading accuracy at T1. Additionally, visual discrimination (β = 0.37), RAN (β = -0.25), word analogy (β = 0.23), and vocabulary (β = 0.20) all uniquely predicted Kanji reading accuracy at T2.

Discussion

In this study, we examined the early cognitive predictors of reading development in syllabic Hiragana and morphographic Kanji in Japanese. The results showed that phonological awareness, RAN, phonological memory, and visual discrimination were associated with Hiragana word reading fluency in Kindergarten, whereas morphological awareness uniquely predicted Hiragana word reading fluency in grade 1. Additionally, RAN, morphological awareness, vocabulary, and visual discrimination all uniquely and longitudinally predicted Kanji reading in grade 1. The findings provided further evidence for the universal and script-specific cognitive predictors of word reading skills in Japanese.

The results indicated first that all phonological processing skills (i.e., phonological awareness, phonological memory, and RAN) contributed to early Hiragana reading. In line with the findings from previous studies in alphabetic orthographies and

Japanese (e.g., Georgiou et al., 2008; Kobayashi et al., 2005), phonological awareness predicted early reading acquisition in Hiragana. Additionally, phonological memory was uniquely associated with the initial word reading fluency in kindergarten. One possible explanation for the results is that beginning readers may lack the advantage of lexical reading processes in which they process larger graphemic units (e.g., morphemic units) to support the decoding of words. Consequently, the children become heavily reliant on phonological awareness and phonological memory to recall the pre-decoded characters of words and assemble the sounds before articulation (Inoue et al., 2020; Sambai et al., 2012). In contrast, neither phonological awareness nor phonological memory predicted later Kanji reading accuracy. It should be noted, however, that phonological awareness in Kindergarten was moderately correlated with Grade 1 Kanji reading ($r=0.41$, see Table 2). Given the fact that phonological awareness was also correlated with RAN ($r=0.43$), the effect of phonological awareness on later Kanji reading might have been underestimated due to the significant effect of RAN on Kanji reading (see Fig. 3).

In turn, morphological awareness and vocabulary were relatively more strongly associated with early Kanji reading than Hiragana reading. This finding is consistent with those of previous studies in Chinese and Japanese (e.g., Hulme et al., 2019; Inoue et al., 2017; Luo et al., 2013; Muroya et al., 2017; Tong et al., 2011). This result may reflect the fact that whereas syllabic Hiragana primarily represents sounds in the spoken language, the basic unit of writing in morphographic Kanji (i.e., characters) is more strongly associated with the unit of meaning (i.e., morphemes and whole words). This characteristic may have resulted in the stronger effects of morphological awareness and vocabulary on Kanji reading over and above the effect of Hiragana reading. Additionally, morphological awareness uniquely contributed to Hiragana reading fluency in Grade 1 after controlling for the autoregressive effect of the same skill in Kindergarten. This may reflect the fact that Japanese children in Grade 1 begin to decode short character strings as morphemic units (see Muroya et al., 2017).

In line with findings from previous studies across alphabetic and non-alphabetic writing systems (e.g., Araújo et al., 2015; Georgiou et al., 2016; Inoue et al., 2020; Song et al., 2016), the study observed that RAN had the strongest impact on reading fluency in Hiragana. Interestingly, the findings further illustrated that RAN was also uniquely associated with reading accuracy in both scripts, and the effect was relatively stronger for Kanji reading than for Hiragana reading (Fig. 3). There are at least three explanations for these findings. First, RAN reflects the efficiency of accessing and retrieving the phonological representations of words from long-term memory (e.g., Georgiou et al., 2020; Torgesen et al., 1994), and this may have driven the unique longitudinal associations between RAN in Kindergarten and word reading skills in both scripts in grade 1. Second, RAN may be associated with reading indirectly via its contributing to the development of orthographic knowledge (Bowers & Wolf, 1993; Martinez et al., 2021). Manis et al. (1999) argued that RAN taps into children's ability to form orthographic representations of words. Indeed, Japanese children are required to learn a large number of Kanji characters, which may have enhanced the observed association between RAN and Kanji reading accuracy. Finally, RAN may play an essential role in learning morphographic scripts,

such as Chinese and Japanese Kanji, because it requires the formation of arbitrary associations between graphic symbols and their names (including pronunciations of irregular/exception words). This tendency would be particularly the case at the initial phase of reading development (Georgiou et al., 2017; Liao et al., 2015). In other words, RAN and Kanji reading may be both tapping common visual–verbal associate learning processes (Liu et al., 2021).

Finally, visual discrimination uniquely predicted Hiragana reading fluency and Kanji reading accuracy. The former association may be partially due to the format of the task used to assess visual discrimination. Indeed, the visual discrimination task required children to process complex figures serially as fast as possible. In other words, the task may have required visual perception and speed of visual processing. According to the psycholinguistic grain size theory (Ziegler & Goswami, 2005), beginning readers of transparent orthographies (e.g., Finnish, Greek, and Japanese Hiragana) focus more on small units within words (e.g., Manolitsis et al., 2017; Inoue et al., 2019). Hence, this characteristic may influence the degree of involvement of serial processing speed in word reading fluency. The results suggested that serial processing efficiency (Altani et al., 2018; Protopapas et al., 2013), which received less attention from studies in Japanese, may play a key role in early fluency development in Hiragana. In turn, the unique association between visual discrimination and Kanji reading accuracy may reflect the role of visual processing in learning to read Kanji characters, which are frequently graphically complex (Hulme et al., 2019; Luo et al., 2013; Tong et al., 2011). Hulme et al. (2019) suggested that visual skills (geometric-figure visual discrimination) were predictive of Chinese word reading in Grade 1 because students heavily rely on basic visual strategies. The current results provided further evidence for the essential role of visual discrimination in early reading development in morphographic scripts (Yang et al., 2013).

An important educational implication of the present findings is that an early assessment of Hiragana reading fluency instead of Hiragana reading accuracy can serve as a predictor of later difficulty among children in learning to read in both scripts. In fact, the results implied that, although Hiragana reading accuracy in Kindergarten does not significantly predict Kanji reading accuracy in grade 1, Hiragana reading fluency in Kindergarten is strongly correlated not only with Hiragana reading fluency but also with Kanji reading accuracy in grade 1 (see Table 2). Another educational implication is that visual discrimination, together with vocabulary and morphological awareness, should be included in assessment batteries and instructional programs for early word reading skills in Japanese (Bowers et al., 2010; Muroya et al., 2017). Although most previous studies in Japanese have mainly focused on the roles of phonological awareness and RAN in reading development, the present study highlighted the roles of morphological awareness and visual discrimination in the development of early reading skills in the two scripts, particularly for Kanji reading.

This study has its limitations, which require further consideration. First, the sample size was relatively small. Thus, caution is required when interpreting the results. To address this concern, the findings should be replicated with a larger and possibly more representative sample. Second, we used single measures to assess each cognitive construct, and the number of items used in some measures were small. In

addition, the elision task used in the study only required children to delete the middle mora in words. As a result, the aspects of the cognitive constructs assessed by each measure were limited, which, in turn, might have caused the potential underestimation of associations between the cognitive skills and reading skills. This may be particularly the case for morphological awareness, which has a multifaced nature and have been assessed with different types of measures (see e.g., Hayashi & Murphy, 2012; Ke et al., 2020). Although it was necessary to reduce testing time and fatigue among kindergarten children, future studies should consider using multiple measures with a larger and more representative items to assess each cognitive construct. Third, measures of orthographic processing or paired associate learning were excluded, both of which have been demonstrated to play roles in reading in morphographic scripts (e.g., Georgiou et al., 2017). This aspect is particularly important to further examine the unique roles of visual discrimination and RAN as predictors of reading development in Japanese. Finally, the study focused only on the transition period from kindergarten to grade 1. As such, the developmental trajectories of reading skills in the two scripts should be examined over a longer period and should range from pre-reading to more proficient reading.

To conclude, the study examined the early predictors of reading development in syllabic Hiragana and morphographic Kanji in Japanese. The results suggested that phonological awareness and phonological memory were uniquely associated with Hiragana reading accuracy and fluency, whereas vocabulary was more strongly associated with Kanji reading accuracy. Moreover, RAN, morphological awareness, and visual discrimination significantly contributed to early reading skills in both scripts. The findings add to the growing body of cross-script research on the cognitive predictors of early reading acquisition by revealing the modulating role of the characteristics of scripts in the relationship between different cognitive factors and word reading skills.

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