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Reading Predictors in Croatian: Contribution of (Meta)Phonological Variables

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Abstract

Phonological awareness (PA), rapid automatised naming (RAN) and working memory (WM) are considered to be the most important factors supporting reading development. However, their relative importance varies across orthographies and age. The goal of this study was to examine reading predictors in Croatian, a language with highly transparent orthography, after three years of formal reading instruction. The study included 80 participants (mean age: 10.07 years). Reading rate and accuracy were measured using lists of words and pseudowords, and PA was measured using phoneme deletion, phoneme addition and spoonerism tasks. RAN was measured using naming of colours, and WM was measured using the WM standardised measure of digit span (WISC-IV-HR) and pseudoword repetition. In order to find the best predictors of reading rate and accuracy for both words and pseudowords, three-stage hierarchical multiple regression was conducted. The results showed that in highly transparent language when reading is automatised, RAN is the most significant predictor of both reading rate and accuracy. Although this study did not show dissociation between the predictors supporting reading speed and reading accuracy, it confirmed the importance of PA as a suppressor variable for RAN in predicting pseudowords reading time.

Keywords: reading predictors, transparent orthography, phonological awareness, rapid automatized naming, reading automatization

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Introduction

Languages differ widely in the way their spoken segments or phonemes are represented in written form by graphemes. Since grasping meaning while reading depends on those differences, they inevitably influence reading development. Research on those differences in the context of reading development and reading disorder leads to an obvious scientific and clinical paradox: conclusions that drive theoretical frameworks and remediation techniques arise mostly from studies in English, which is hardly a prototypical representative of European orthographies. There is substantial evidence that the consistency of phoneme-grapheme mappings influences the pace of reading development (Seymour et al., 2003; Share, 1995); thus, it is justified to question the validity of conclusions that are derived from opaque orthographies and applied to transparent ones. The predictive role of cognitive mechanisms underlying reading development might vary across different orthographies at various ages.

Research on prereading skills (e.g. Carroll & Snowling, 2004; Puolakanaho et al., 2007) and cognitive predictors of reading (e.g. Landerl et al., 2013) has revealed three important phonological and metaphonological factors supporting reading development: phonological awareness (PA), rapid automatised naming (RAN) and working memory (WM). The goal of this study was to examine reading predictors in Croatian, a language with highly transparent orthography, after three years of formal reading instruction.

Phonological Awareness

PA is a metaphonological skill that refers to the ability to recognise and manipulate units smaller than words – onset, rimes, syllables and phonemes – and it is considered to be one of the best predictors of reading. Numerous studies show that children with good PA become fluent readers, while children with reading disorder exhibit significant difficulties in tasks requiring different levels of PA (Brady & Shankweiler, 2013; Swan & Goswami, 1997). PA develops from bigger to smaller units (Anthony et al., 2003), finishing with the awareness of phonemes – phonemic awareness – which is completely developed only after systematic reading instruction has begun (Goswami & Bryant, 1990). Phonemic awareness represents mental insight into the phonological structure of words and enables the development of decoding, even of words not stored in the mental lexicon (Ehri, 1992). It has been shown that PA is highly predictive of early reading development in orthographically transparent languages. However, research at later ages shows weaker connections between phonemic awareness and reading measures. For example, research conducted in Turkish, Finish, Greek and German shows that participants have very high achievement in PA tasks early after systematic reading instruction has begun (Durgunoğlu & Öney, 1999; Holopainen et al., 2002; Wimmer et al., 1991). Due to direct and unambiguous mappings of phonological and orthographical units, the development of decoding is fast and simple, and PA is consequently further developed. As readers of languages with transparent orthographies develop decoding, they rapidly converge to similar PA levels and the correlation between PA and reading weakens (Ziegler et al., 2010). The role of PA in Croatian has been investigated in several studies. Zaretsky et al. (2009) confirmed that PA is a code-related skill that significantly correlates with early literacy measures such as word recognition and decoding. Performing factor analysis of the rhyme variable, Kuvač Kraljević et al. (2019) have confirmed that rhyme is distributed equally onto both syllabic and phonemic awareness factors. The authors conclude that rhyme plays a role in the transition from syllabic to phonemic awareness during the preschool period. Based on a 3-year follow-up, Kolić-Vehovec (2003) confirmed that basic components of PA can predict reading skills in the first grade, especially reading fluency. Keresteš et al. (2019) in their 4-year follow-up study focused on PA, WM and morphosyntactic awareness as potential predictors of rank-order development of reading and writing skills. While morphosyntactic awareness proved to be a significant predictor for all reading and writing variables, PA contributed significantly to explain changes in reading comprehension and word spelling accuracy, but not in the word decoding speed.

Rapid Automatised Naming

RAN is usually described as the ability to rapidly retrieve phonological codes from the mental lexicon or long-term memory (Wagner et al., 1993). It includes a series of processes, such as attention, perception, memory and further retrieval of conceptual, semantic and phonological representations of words, but also motoric planning and articulatory processes (Wolf et al., 2000). Each of these processes is temporally limited, fast and automatised. The RAN measure was first developed by Denckla and Rudel (1974). In the task, participants are supposed to rapidly name numbers, digits, colours or objects that are randomly repeated. A pool of research has confirmed that RAN predicts reading achievement in orthographies of different depth (overview in Wolf et al., 2000). However, Wolf and Bowers (1999) emphasised that rapid naming has a stronger predictive role in transparent orthographies. RAN is considered to be a better predictor of reading fluency than accuracy (e.g. Vukovic et al., 2004; Wolf et al., 2000; but see Savage et al., 2008 for contribution to reading accuracy). Further, some research shows that RAN is a stronger predictor of reading in transparent languages than PA (de Jong & van der Leij, 1999; Georgiou et al., 2008; Wimmer et al., 2000). Nevertheless, conclusions in this area of research are not unambiguous and some researchers suggest that the role of RAN depends not only on orthography, but also on stimuli used. While some research shows that alphanumeric stimuli are correlated to reading (see Neuhaus et al., 2001), but colours are not (Stringer et al., 2004), or that correlations are different at different ages (Ibrahim, 2015); other studies exploring the role of RAN do not find differences between the stimuli and suggest that also non-alphanumeric stimuli efficiently predicts reading in transparent orthographies (e.g. Di Filippo et al., 2005). Of all the predictors of reading, RAN is the least explored in the Croatian language. Nevertheless, the sparse results of such research are consistent with findings in other languages: children who are slow in performing RAN tasks process graphemes more slowly and consequently are slower in acquiring orthographic lexical representations (Ivšac Pavliša & Lenček, 2011; Kelić, 2017).

Working Memory

Within language research, WM is usually observed through a model that describes it as a complex system whose components are specialised for certain processes and certain types of stimuli (Baddeley, 1996; Baddeley & Hitch, 1974). Visual information is processed in the visual-spatial sketchpad, while language information enters the phonological loop. The third component, the central executive, supports various functions, including retrieval from long-term memory, manipulation of information, and retention or switching of attention. In 2000, Baddeley added another component, the episodic buffer, a temporary store that integrates information from other components (Baddeley, 2000). WM difficulties are one of the most important predictors of reading disorder (Ramus & Ahissar, 2012; Swanson et al., 2009). To establish stable phoneme-grapheme mappings during reading, the acoustic representation of phonological units must be retained in short-term memory. Difficulties in retaining the information will result in difficulties reading, learning new words and in mapping their phonological and orthographic representations (Gathercole & Baddeley, 1993). WM also plays an important role in the awareness of phonological units (Rončević Zubković, 2010). Development of PA is strongly connected to WM because this mechanism supports complex tasks that include different levels of representations (Ramus, 2001). There is a strong correlation of PA with the WM components of the phonological loop (e.g. Oakhill & Kyle, 2000) and central executive (Alloway, 2009). Finally, efficient WM enables phonological coding and decoding (Wagner et al., 1994).

In research on WM, probably the most commonly used tasks are digit span and pseudoword repetition. Number repetition is considered to be a measure of the phonological loop, while repeating the numbers backwards gives insight into functionality of the central executive because it involves manipulation along with retention. Pseudoword repetition is usually considered to be one of the best measures of WM because their repetition is not supported by long-term memory (Gathercole & Baddeley, 1993). Research shows that number repetition and pseudoword repetition are not identical measures. Children with language disorder, in comparison to typically developing peers, show bigger difficulties in the pseudoword repetition than in the number repetition (Archibald & Gathercole, 2007). Number repetition proved to be more strongly correlated to the repetition of the individual syllables than to pseudoword repetition (Kelić et al., 2016). This discrepancy indicates that performance in pseudoword repetition cannot be completely explained by the WM, and that it depends on the phonological structure of the words used.

Contribution of (Meta)Phonological Variables in Orthographically Transparent Languages

Despite the consensus that phonological awareness, lexical retrieval measured by RAN and phonological working memory support reading, as explained above, there are some open questions concerning their role in reading and relative significance in different orthographies. Focusing on the reading disorder, Wolf and Bowers (1999) proposed a double-deficit hypothesis according to which PA and RAN are partly independent and support different reading routes. Their hypothesis integrates premises brought by dual-route model of reading (Coltheart, 2005) where grapheme-phoneme conversions are considered essential for reading pseudowords, while fast access to phonological lexicon directly from orthographic representations allows reading irregular words in opaque orthographies or more frequent words in transparent orthographies (Valle-Arroyo, 2013).

Although the vast majority of research is English-based leading to possible misinterpretations, few crosslinguistic studies explored predictors in languages with different orthographic complexity. Ziegler et al. (2010) studied five languages (Finnish, Hungarian, Dutch, Portuguese and French) and showed that PA was the strongest predictor of reading speed and accuracy in all languages except in the most transparent one: in Finnish PA and vocabulary equally strongly predicted reading accuracy, while vocabulary was the strongest predictor of the reading rate. The relative impact of PA was modulated by orthography - it was weaker in transparent orthographies. Landerl et al. (2013) in their study of six languages (English, French, Dutch, German, Hungarian, Finnish) showed that PA and RAN were the best predictors of reading, regardless of the orthography. In a large study of five orthographies (English, French, German, Hungarian, Finnish), Moll et al. (2014) showed that PA and WM accounted for higher amounts of unique variance in reading accuracy, while RAN was the best predictor of reading fluency proving the differential association of PA and RAN with reading accuracy and rate. Georgiou et al. (2008) also showed that in transparent orthographies two routes may be necessary to explain the reading process, as suggested by Wolf and Bowers (1999).

Considering the differences in the developmental path of reading in different orthographies, it is reasonable to question the predictive values of cognitive and linguistic constraints supporting reading in different languages since well-defined reading predictors enable more precise definition and detection of the reading disorder but also direct remediation techniques.

Present Study

Since transparent orthographies are still much less investigated than opaque ones and available research has given contradictory and ambiguous results, the goal of the present study is to investigate the predictive role of metaphonological (PA) and phonological variables (RAN, WM) in Croatian after three years of formal reading instruction. In order to investigate the orthographical route of reading as well as the phonological route (or decoding ability), reading predictors for both word reading and pseudoword reading were examined, and both accuracy and reading rate were measured.

Taking into account predictions of the double-deficit hypothesis (Wolf & Bowers, 1999), the study aimed to address the following research questions:

1. Is there a differential association of PA and RAN with reading accuracy and reading speed after three years of formal education? Additionally, what is the predictive role of the WM on the same skills?
2. Are two routes necessary to explain the reading process in Croatian, i.e. is there the same contribution of the phonological and orthographic route in reading in Croatian at the age of ten?
3. In keeping with findings from previous research in different orthographies, it can be assumed that PA will be a better predictor of reading accuracy and RAN of reading speed. Specifically, in condition of reading pseudowords (phonological route) and reading words (orthographic route), PA will be a better predictor of reading pseudowords and RAN of reading words.

Method

Participants

This study included 80 participants (mean age: 10.07 years, age range: 9.11 – 11.0, 29 boys and 51 girls). All participants had three years of formal reading instruction - they were students in the fourth grade. All participants had cognitive abilities within average span for the age (IQ $\geq$ 80, mean IQ: 102, range: 80 – 132), measured using Coloured Progressive Matrices, Raven et al., 1999), intact visual and hearing abilities. Since there is no standardized reading test for Croatian, reading abilities of the children in the sample were estimated by their teachers and school psychologists and speech and language pathologist who were assisting the recruitment: children who were diagnosed with reading or/and language impairment and children whose parents started or will be contacted to start the procedure to be diagnosed (waiting for the Individualized Educational Program) were excluded from the sample. All the other children with the informed consent participated in the study. In this way we assured that there were no children with reading difficulties in the sample, but also that not only superb readers are selected.

Instruments and Procedures

Materials used in the study included a list of words and a list of pseudowords used to evaluate reading, phonemic awareness tasks and pseudoword repetition (see Kelić, 2017, 2019; Kelić et al., 2016 for more detailed explanation of materials). WM was examined using digit span (WISC-IV-HR), and RAN was assessed through naming colours (De Luca et al., 2005).

The ethical approval for this research was issued by the Faculty of Education and Rehabilitation Sciences of University in Zagreb (ERF-EP/HR3.2.01-0247/2015). The assessment was conducted with each participant individually in the school. Data was collected by speech and language pathologist and psychologist. All participants responded to all items, there were no stopping rules in any of the tasks, except in the digit span (WISC-IV-HR). Three schools participated in the research, two from the City of Zagreb and one from Zagreb County. The information sheet provided by the authors were given to parents by the school psychologists and speech and language pathologists who also collected the informed consents. Children's consent was obtained by the researchers themselves before the procedure.

List of Words and List of Pseudowords For Measuring Reading

As there is no standardized list of words and pseudowords, it was first necessary to create them controlling phonological rules and restrictions of the Croatian language. Materials constructed to measure reading were developed to reflect the average Croatian text in the length and complexity of the words used. To ensure that, phonological complexity of Croatian, orthographic frequency and lexical frequency needed to be taken into account.

The list of words constructed to evaluate reading contained 104 words. While constructing the list, several phonological constraints were taken into account: number of syllables, syllable structure, frequency of graphemes. Due to the lack of data for the Croatian language, these constraints were obtained by analysis of three samples (20 000 tokens in each) from the Croatian web corpus (hrWaC; Ljubešić & Klubička, 2014). Analysis of the lexical words in the samples revealed the distribution of words according to the number of syllables and frequency of individual syllabic structures.

From these data, a list of words was constructed where each group of words of a certain length (number of syllables) contained an equal number of frequent and less frequent words. Frequent and less frequent words were balanced in their syllable structure. The group of frequent words included words that appear in the first 1000 words in the vocabulary of child language (Lukić, 1983), while low-frequency words were selected from the words with frequency 1. To make sure that the frequency of graphemes in the reading list reflected their distribution in the language, statistical analysis was conducted. There was no difference between the distribution of the graphemes in the list of words and in the corpus samples.

The list of pseudowords contained 44 pseudowords. To construct pseudowords the same phonological constraints were used as for the word list. Pseudowords were constructed by combining attested syllables from the corpus samples. To control the frequency of the bigrams at the border of the chosen syllables, analysis was conducted in the hrWaC (Ljubešić & Klubička, 2014), which confirmed that the distribution of the frequencies of bigrams followed a normal distribution; thus, most bigrams were of medial frequency.

For both lists, participants were given the instruction to read words/ pseudowords in columns as fast and accurately as they could. For each list separately, speed and accuracy were measured. The speed was measured in seconds from the moment when the child began to read. Accuracy was expressed as the number of errors.

Phonological Awareness Tasks

To test PA, three tasks were used: phoneme deletion, phoneme addition and spoonerisms. Every task contained eight items. In deletion and addition tasks, target phonemes were at the initial, final or middle position. Difficulty of the task varied according to the structure of the syllable where the target phoneme was added or deleted (e.g. initial phoneme in *KOSA without K becomes OSA*; phoneme in a consonant cluster in *STVAR without V becomes STAR*; middle phoneme in *BAKA with added LJ becomes BAKLJA*). In the spoonerisms, participants had to replace the first phonemes in two presented words (e.g. *ŠAPA – KUMA* becomes *KAPA – ŠUMA*). Also in this task, difficulty varied according to the structure of the target syllable.

In the PA tasks, participants were given the instruction with an example. For the deletion task, participants received the instruction to delete the target phoneme from the given word and to say the new word that emerged. Participants were instructed that the newly formed words were always real Croatian words. In the additional task, participants were instructed to add the target phoneme to the word at any position with the purpose of creating a new, real word. In the spoonerism task, participants heard two words and were told to replace the first phonemes: they were supposed to put the first phoneme of the first word at the beginning of the second word and vice versa. The example was solved together with the participant to ensure a good understanding of the instruction.

In PA tasks only accuracy was measured, and one point was given for each correct item (0-8 in each task). One total PA score for all three tasks was calculated summing the correct answers in deletion, addition and spoonerisms (Max = 24). PA scores were expressed as a proportion of correct responses.

RAN

To test RAN, naming of colours was used (De Luca et al., 2005) since there is evidence that the same processes are involved in both alphanumeric and non-alphanumeric RAN and there are no differences in their predictive value (Di Filippo et al., 2005; Landerl et al., 2013). Additionally, due to the lack of standardized RAN test in Croatian, colour version of the task was the most convenient since no adaptation was needed (as the frequency of graphemes in alphanumeric or frequency of words in object version of RAN task). The task consisted of 50 fields (1 x 1 cm) arranged in 10 rows. Five colours were used (red, green, blue, yellow and black) and were randomly repeated (for description see Di Filippo et al., 2005).

In the RAN of colours, participants received a practice template consisting of five rows of coloured squares. Participants received the instruction to name the colours as fast as they could and to make sure not to skip the squares. After practising, participants named the colours in the testing template.

The score in RAN was expressed as the amount of time (in sec) needed to name the list of items presented.

WM Tasks

To test WM, two tasks were used: the digit span from Wechsler's Intelligence Scale (WISC-IV-HR; Wechsler, 2009) and pseudoword repetition. The digit span measures repetition of numbers forward and backwards, thus the child needs to repeat the orally presented numbers in the same order or in the reverse order, respectively. The standard instruction from the test manual was used. The score in the digit span from Wechsler's Intelligence Scale was expressed in standard scores.

The pseudoword repetition task consisted of 16 pseudowords of different complexity. Pseudowords varied in length (number of syllables) and syllable structure. The shortest words had two syllables, and the longest words had five syllables. Syllable structure was determined by the complexity of the onset and coda. The easiest pseudoword had the structure CV-CV, while the most complex one had the structure CCV-CV-CV-CV-CCVCC. Pseudowords for this task were constructed using the same method as pseudowords for the reading list. Syllables were attested in the corpus samples. Bigrams at the syllable borders were normally distributed.

In the pseudoword repetition task, participants were told that they would hear some unusual words that had no meaning and they should repeat them exactly as they heard them. Systematic articulation errors were ignored. Every correct response was awarded 1 point, for a maximum score of 16 points.

Results

In order to investigate reading predictors, a series of correlation and regression analyses were conducted. They were conducted separately for word reading time and accuracy and pseudoword reading time and accuracy.

First, we tested differences between the boys and girls in reading, phonemic awareness tasks, pseudoword repetition, working memory and RAN (Table 1). Results showed that there were no gender differences in all examined variables, therefore, descriptive statistics, distribution normality parameters (Table 2), intercorrelations and regression analysis were performed for participants overall (Table 3, Table 4, and Table 5).

Table 1

Summary of Group Means, Standard Deviations and Independent Samples Results Comparing Boys and Girls on all Examined Variables

	Girls			Boys			*t*-test
	N	*M*	*SD*	*N*	*M*	*SD*	
Word reading time	51	104.14	25.97	29	109.93	35.52	0.77
Word reading errors	51	1.75	2.47	29	2.41	3.03	1.07
Pseudoword reading time	51	57.76	30.26	29	56.62	26.57	-0.17
Pseudoword reading errors	51	2.35	2.11	29	2.66	3.74	0.40
Phonological awareness	51	.81	.13	29	.81	.15	0.07
RAN	51	38.14	5.96	29	38.08	7.55	-0.04
Digit span	51	10.92	2.27	29	10.62	2.94	-0.51
Pseudoword repetition	51	14.45	1.22	29	14.52	1.57	0.21

$^{*}p < .05$; $^{**}p < .01$.

Distribution normality parameters (Table 2) indicate that Word reading time, PA, Digit span, and Pseudoword repetition follow within parameters of symmetrical distributions. However, only PA, Digit span, and Pseudoword repetition have distributions within expected tailedness parameters. Distribution normality parameters for Word reading errors, Pseudoword reading time, Pseudoword reading errors, and RAN indicate positively skewed and too peaked distributions. Probability distribution indicates a violation of the assumption of normality for all examined variables. Furthermore, we examined the residuals of the regression by analysing a Normal probability plot and a Normal quantile plot to test the normality of distributions (Casson & Farmer, 2014). Since the deviations from the straight line were minimal, we concluded that the residuals of the regression are normally distributed for all dependent variables.

Table 2

Summary of Group Means, Standard Deviations, Minimum, Maximum Scores, and Distribution Normality Parameters for All Examined Variables

	M	*SD*	MIN	MAX	Skewness	Kurtosis	1-Sample *K-S*
Word reading time	106.24	29.70	56	213	0.86	1.06	.11*
Word reading errors	1.99	2.69	0	14	2.16	5.97	.23**
Pseudoword reading time	57.35	28.21	17	176	1.19	2.74	.11*
Pseudoword reading errors	2.46	2.79	0	15	2.16	6.46	.19**
Phonological awareness	.81	.14	.46	1	-0.41	-0.57	.11*
RAN	38.12	6.53	28.11	62.19	1.17	1.69	.14**
Digit span	10.81	2.52	5	19	0.50	0.58	.13**
Pseudoword repetition	14.48	1.35	11	16	-0.83	0.09	.23**

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

Intercorrelations between the multiple regression variables (Table 3) show a large number of significant correlations between the examined variables.

Table 3

Intercorrelations Between the Multiple Regression Variables

	Word reading errors	Pseudoword reading time	Pseudoword reading errors	Phonological awareness	RAN	Digit span	Pseudoword repetition
Word reading time	.54**	.45**	.42**	-.40**	.50**	-.38**	-.29*
Word reading errors		.46**	.68**	-.37**	.33**	-.40**	-.18
Pseudoword reading time			.57**	.08	.42**	-.09	.07
Pseudoword reading errors				-.27*	.47**	-.30**	-.13
Phonological awareness					-.28*	.62**	.37**
RAN						-.22	-.17
Digit span							.38**

*$p < .05$, **$p < .001$.

All reading measures show high to moderate correlations where reading accuracy (expressed in the number of errors) has a positive correlation with reading time. PA has a moderate correlation with working memory, then pseudoword repetition, and to a lower degree with RAN. Furthermore, PA has moderate correlations with word reading measures and a small correlation with pseudoword reading accuracy but does not correlate with pseudoword reading time. RAN has moderate to high correlations with all reading measures. Also, RAN does not correlate with working memory and pseudoword repetition measures. Working memory measures have significant moderate to strong correlations to all reading measures except pseudoword reading time. Pseudoword repetition has a low degree of correlation with word reading time and does not correlate with other reading measures.

A three-stage hierarchical multiple regression was conducted in order to examine to which extent PA, RAN, WM and Pseudoword repetition explain the variance in reading accuracy and reading time. PA was entered at stage one of each regression, RAN at stage two and Digit span and Pseudoword repetition at stage three. Table 4 and 5 show the results of these analyses. The Predictor variables were entered in this order according to the literature pointing out PA as the most important predictor in reading (Landerl et al., 2013; Ziegler et al., 2010) and phonological theory of reading development where PA initiates self-teaching device which allows decoding word forms that are never heard before (Ehri, 1992). As reading development progresses, mappings between phonology and orthography are learned and the speed of reaching the entry in the lexicon (RAN) and the ability to retain that information (WM) are becoming more relevant (Gathercole & Baddeley, 1993; Wolf et al., 2000).

Prior to conducting a hierarchical multiple regression, the relevant assumptions of this statistical analysis were tested. Initially, a sample size of 80 was deemed adequate given four independent variables to be included in the analysis (Tabachnick & Fidell, 2001). The assumption of singularity was also met as the independent variables (PA, RAN, Digit span and Pseudoword repetition) were not a combination of other independent variables. An examination of correlations revealed that no independent variables were highly correlated. Furthermore, the collinearity statistics (i.e., Tolerance and VIF) were all within accepted limits, therefore, the assumption of multicollinearity was met (Hair et al., 1998). An examination of the Mahalanobis distance scores (Mahalanobis, 1936) indicated no multivariate outliers. Residual and scatter plots indicated the assumptions of normality, linearity and homoscedasticity were all satisfied (Hair et al., 1998; Pallant, 2011).

Word Reading – Time and Number of Errors

The overall regression model predicted 35% of variance in word reading time and 23% of variance in word reading accuracy. PA predicted approximately 16% of variance in word reading time ($F_{\text{Change}}(1, 78) = 14.99$; $p < .01$) and approximately

14% of variance in word reading accuracy ($F_{Change}(1, 78) = 12.30$; $p < .01$). Adding the RAN into step two of the regression model predicted additional 16% variance in word reading time ($F_{Change}(1, 77) = 19.01$; $p < .01$) and additional 5% of variance in word reading accuracy ($F_{Change}(1, 77) = 5.40$; $p < .05$). After controlling for PA and RAN, working memory measures did not contribute significantly to the variance in word reading time and accuracy, although digit span reached marginal significance ($p = .053$) as a predictor for word reading accuracy. The overall model was significant for reading time as well as for reading accuracy.

Standardized regression coefficients of individual predictors indicate that only RAN scores significantly predicted word reading time and accuracy, with higher RAN scores, i.e. prolonged retrieval of phonological codes, being associated with slower reading and more reading errors.

Table 4

Regression Statistics Showing Phonological Awareness, Rapid Automatized Naming, Working Memory and Pseudoword Repetition as Predictors of Word Reading Time and Accuracy

Step		Word reading time	Word reading errors
1	Phonological awareness	$-.40^{**}$	$-.37^{**}$
	ΔR^2	$.16^{**}$	$.14^{**}$
	F (1, 78)	14.99^{**}	12.30^{**}
2	Phonological awareness	$-.28^{**}$	$-.30^{**}$
	RAN	$.43^{**}$	$.25^{*}$
	ΔR^2	$.16^{**}$	$.05^{*}$
	F (1, 77)	19.01^{**}	5.40^{*}
3	Phonological awareness	-.15	-.15
	RAN	$.41^{**}$	$.24^{*}$
	Digit span	-.15	-.26
	Pseudoword repetition	-.10	.02
	ΔR^2	.03	.04
	F (2, 75)	1.61	1.97

$^{*}p < .05$; $^{**}p < .01$.

Pseudoword Reading Time and Number of Errors

The overall regression model predicted 25% of variance in pseudoword reading time and 26% of variance in pseudoword reading accuracy. PA predicted approximately 7% of variance in pseudoword reading accuracy ($F_{Change}(1, 78) = 6.1$; $p < .05$), but was not a significant predictor of pseudoword reading time. Adding the RAN into step two of the regression model predicted additional 17% of variance in pseudoword reading accuracy ($F_{Change}(1, 77) = 16.82$; $p < .01$) and approximately 21% of variance in pseudoword reading time (F_{Change} (1, 77) = 20.95; $p < .01$). PA is uncorrelated with the pseudoword reading time but significantly correlates with

RAN (r = -.28). Therefore, PA controls for pseudoword reading time irrelevant variance in the RAN, which increases the predictive power of RAN indicating the suppressor effect of PA in a regression model (Watson et al., 2013). After controlling for PA and RAN, working memory measures did not contribute significantly to the variance in pseudoword reading time and accuracy, although the overall model was significant.

Standardized regression coefficients of individual predictors indicate that only RAN scores significantly predicted pseudoword reading accuracy, with higher RAN scores being associated with more reading errors. Furthermore, PA and RAN scores significantly predicted pseudoword reading time, with higher PA and RAN scores being associated with slower pseudoword reading.

Table 5

Regression Statistics Showing Phonological Awareness, Rapid Automatized Naming, Working Memory and Pseudoword Repetition as Predictors of Pseudoword Reading Time and Accuracy

Step		Pseudoword reading time	Pseudoword reading errors
1	Phonological awareness	.08	-.27*
	ΔR^2	.01	.07*
	F (1, 78)	0.49	6.10*
2	Phonological awareness	.21*	-.15
	RAN	.48**	.42**
	ΔR^2	.21**	.17**
	F (1, 77)	20.95**	16.82**
3	Phonological awareness	.30*	-.04
	RAN	.48**	.42**
	Digit span	-.21	-.19
	Pseudoword repetition	.12	.03
	ΔR^2	.03	.02
	F (2, 75)	1.64	1.12

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

Discussion

It is well documented that the predictive role of PA, RAN and WM in reading depends on orthography. Although all three constructs are predictive of reading speed and accuracy, their relative importance is different in different orthographies and depends on the age and amount of systematic reading instruction. In this study, the predictive role of PA, RAN and WM was examined in Croatian orthography after three years of systematic reading instruction.

The regression analysis showed that only PA and RAN are related to the reading measures. Although their relative importance slightly varied among the measures, in this study RAN proved to be the most relevant predictor of reading among (meta)phonological variables after three years of reading instruction (Table 6).

Table 6

The Significant Predictors Obtained from the Final Model of The Regression Analysis for Four Reading Variables

	WORDS	PSEUDOWORDS
TIME	RAN	RAN PA
ERRORS	RAN	RAN

When examining the reading time needed to read the list of words, RAN proved to be the most important predictor. These results are in line with the research showing that in more transparent languages, RAN is better at predicting the rate of reading than PA (de Jong & van der Leij, 1999; Wimmer et al., 2000). It is often stated that in transparent orthographies, results in the phonological awareness tasks are near the maximum (e.g., in Dutch already in the 2nd grade according to de Jong & van der Leij, 1999; in German after three years of schooling as reported in Landerl & Wimmer, 2000). In this study, although results in the PA tasks were high (81%), the complexity of the tasks ensured that there was no ceiling effect. However, it should be taken into consideration that some researchers argue that complex PA tasks, such as the deletion, addition and spoonerism tasks used in this study, give more information about orthographical than phonological awareness of the readers (Ziegler et al., 2010).

In contrast, in the model that explained the highest amount of variance in the time needed to read pseudowords, both RAN and PA proved to be significant. This result is especially interesting since the double-deficit hypothesis suggests that PA more strongly predicts reading accuracy than reading fluency (Wolf & Bowers, 1999). When observing the correlation between the PA and Pseudoword reading time, significant negative correlation would be expected, indicating that higher accuracy in the PA tasks leads to shorter reading time or faster reading. However, as can be seen in Table 3, while there is significant correlation between the PA and other reading variables, there is no correlation between PA and the time needed to read pseudowords. This can imply that participants were sorting out the phonemes or syllables, applying the grapheme-phoneme mapping rules and then connecting the sounds, namely blending the sounds into words. Thus, well-developed PA would support this process, but at the same time applying this mechanism would lead to slower reading of pseudowords. Interestingly, this cannot be observed in reading words where the reading process is obviously automatised and better supported by the ability to retrieve phonological codes in a fast and automatic manner.

As mentioned before, although the double-deficit hypothesis suggests that PA is a better predictor of reading accuracy, in this study RAN better explained the examined criteria variables. For the accuracy of reading words and pseudowords, RAN was the only significant predictor in the final model of the analysis. WM was not a significant predictor of any of the examined variables. The role of WM in reading can be explained in the light of monitoring comprehension – the orthographic and phonological representation of the decoded word is kept in the working memory while connecting it to a semantical lexicon and retrieving the meaning. If the word is read erroneously, the meaning is not found and readers with a better WM capacity will start again and correct the word. Since in this study only reading of isolated words and pseudowords was measured, where pseudowords have no meaning, and among words there were also words with the low lexical frequency, the role of the WM was not prominent.

In the present study, RAN proved to be the most significant predictor of all reading variables measured. Another study has pointed out phonological awareness as the most important predictor of reading in orthographically transparent Croatian. While both PA and RAN were related to reading, their association with reading speed and accuracy was differential (Kelić, 2017). In that study, which included typical readers but also participants with reading disorder (mean age: 10.48 years, age range: 9.92 – 11.0), the best predictors of accuracy were PA and WM, while the best predictors of reading speed were reaction time in the PA tasks and RAN. In the present study, reaction time in the PA tasks was not measured, and the accuracy in the PA tasks was not the most important predictor of reading accuracy, showing that when reading is automatised, individual differences are homogenised and PA becomes a less important predictor, as many researchers suggest (Holopainen et al., 2002; Papadopoulos, 2001; Ziegler et al., 2010). In another study exploring reading predictors in Croatian readers, PA proved to be a significant predictor of reading comprehension and word spelling, but did not predict word decoding speed, the only decoding measure tackled in the study (Keresteš et al., 2019). These results are in line with our findings for reading speed. In contrast, when the sample contains a substantial proportion of nonproficient readers, PA is the most important predictor of the reading accuracy and there is dissociation between the mechanisms supporting reading accuracy and reading speed. In an attempt to classify a group of children with dyslexia based on three variables (reading performance, PA, RAN), both PA and RAN contributed to differentiation of the groups: reading more slowly but more accurately was characterised by good PA and slower RAN, while faster but more erroneous reading was connected to lower scores in PA tasks and faster RAN (Kelić et al., 2018).

Both studies, Kelić (2017) and Kelić et al. (2018), identify RAN as the most important predictor of reading speed. Automatization of reading leads to the shift in cognitive processes that support reading fluency. After a substantial amount of systematic reading instruction, RAN becomes the most important predictor of reading fluency (Vaessen et al., 2010). In the present study, RAN was measured by naming colours; thus, the results support the notion that naming non-alphanumeric stimuli is also connected to reading measures, as shown by Wimmer et al. (2000) as well as Brizzolara et al. (2006).

This study showed that in typical Croatian children after three years of reading instruction, reading is mainly supported by the orthographic route. However, the contribution of PA in reading time for pseudowords shows that phonological route is used when reading the words without meaning, supporting the dual-route model. The list of words used in this study contained both words with high lexical frequency and words with low lexical frequency to ensure lexical diversity. Words were chosen from the corpus of children's expressive written language, thus we can hypothesize that those words, although with low frequency, are still present in the child's vocabulary, especially in the passive lexicon, thus mainly read by the orthographic route. As mentioned above, in comparison, children with reading disorder with the same amount of reading instruction, rely more on phonological route since their reading is not fully automatised. Ardila and Cuetos (2016) in their theoretical analysis of the applicability of the dual-route reading model to Spanish emphasize that the potential application of the model in languages with transparent orthography is mediated by the subjects' reading experience. We can assume that a similar process occurs in Croatian: as the reading experience increases, speed increases and orthographic reading becomes predominant. Phonological route might represent initial reading strategy, which is relatively rapidly abandoned due to the transparency of the language (Ardila & Cuetos, 2016). In this study there was no dissociation between the reading speed and accuracy - both reading components were better predicted by RAN, supporting the findings that in transparent orthographies the speed of lexical retrieval is the most important component defining proficient readers.

Limitations

There are some limitations in this study that should be addressed in future research. The sample of this study was rather small and limited to the schools in the capital. Due to the lack of standardized reading test, participants could not be precisely categorized as average, advanced or struggling readers. This study did not tackle readers with the reading disorder and it should be kept in mind that predictors in this group of readers could differ from our results, the same as for the very advanced readers. Although no differences between male and female participants in our studies were shown, it is advisable in the future research to balance the sample population by gender. It should be kept in mind that the obtained results should not be generalized across different time points, thus different reading predictors can prove to be important in the early reading period, in later school periods or in adulthood. To explore the contribution of the predictors, as well as the importance of the two reading routes in reading development, a longitudinal study is needed. This study focused on contributions of (meta)phonological skills to reading. Future research should tackle also other linguistic domains, most importantly vocabulary which many studies highlight as the best predictor of reading in fluent readers of transparent orthographies (e.g. Ziegler et al., 2010).

Conclusion

Identifying cognitive and language predictors of reading performance is an important question that gives guidelines for the identification of poor readers and development of remediation techniques. This study investigated the predictive role of PA, RAN and WM in Croatian, both for reading words and reading pseudowords. The results showed that in highly transparent language when reading is automatised, RAN is the most significant predictor of both reading rate and accuracy. It could be concluded that after three years of formal education there is no more dissociation between the predictors supporting reading fluency and reading accuracy, rather the shift towards the predominant role of the speed of lexical retrieval.

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Prediktori čitanja u hrvatskome jeziku: Doprinos (meta)fonoloških varijabli

Sažetak

Fonološka svjesnost, brzo automatizirano imenovanje i radno pamćenje smatraju se najvažnijim čimbenicima koji podupiru ovladavanje čitanjem, no njihova relativna važnost ovisi o dobi te o pravopisu kojim dijete ovladava. Cilj je ovoga rada ispitati prediktore čitanja u hrvatskome jeziku, koji ima proziran pravopis, nakon tri godine sustavne poduke u čitanju. U istraživanje je uključeno 80 sudionika (prosječne dobi 10.07 godina). Kriterijske varijable, brzina čitanja i točnost čitanja mjerene su čitanjem liste riječi i liste pseudoriječi. Fonološka je svjesnost ispitana zadatcima brisanja i dodavanja fonema te zadatkom premetanja, a brzo imenovanje zadatkom imenovanja boja. Radno je pamćenje ispitano ponavljanjem pseudoriječi i suptestom raspona pamćenja brojeva (WISC-IV-HR). Da bi se provjerila prediktivnost promatranih varijabli, provedena je hijerarhijska regresijska analiza. Rezultati su pokazali da je u jeziku s prozirnim pravopisom nakon tri godine sustavne poduke brzo automatizirano imenovanje najznačajniji prediktor i brzine čitanja i točnosti čitanja. Iako ovo istraživanje nije pokazalo disocijaciju prediktora koji podupiru brzinu čitanja i točnost čitanja, potvrdilo je važnost fonološke svjesnosti kao supresijske varijable za brzo imenovanje u predviđanju brzine čitanja pseudoriječi.

Ključne riječi: prediktori čitanja, proziran pravopis, fonološka svjesnost, brzo automatizirano imenovanje, automatizacija čitanja

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