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Contents

A Social Representation of Organ Donation. Factors Influencing Donation Availability
Diana Todeancă, Andrei Holman, Maria Nicoleta Turliuc, Lorena Antonovici 5

Intrusive Images in Trauma Film Paradigm. The Role of Peritraumatic Tasks, Emotional Regulation Strategies, and Emotional States
Cornelia Măirean, Livia Gliga 23

The Assertive Sense of Relational Entitlement, Emotions and Couple Satisfaction: a Mediation Model
Maria Nicoleta Turliuc, Octav Sorin Candel 41

Organizational Justice and Trust in Managers as Factors of Organizational Commitment
Sebastian Urieși 57

The Predictors of Dyslexia in a Regular Orthography
Katalin Tiron, Alois Gherguț 67

Different Perspectives on Narcissism in Organizational Contexts – a Review and Future Research Directions
Oara Prundeanu, Ticu Constantin, Octav Sorin Candel 93

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The predictors of dyslexia in a regular orthography

Katalin Tiron[1]*, Alois Gherguţ[1]

Abstract: In a technologized world, where sometimes communication is reduced to texting, we need to read so that we can socialize (Light & McNaughton, 2013). Learning to read is crucial nowadays. Scientists have tried to find out what are the clues that could lead to the early identification of children with dyslexia and what measures are necessary to be able to compensate for the reading disorder as effectively as possible. This systematic review aims at identifying the predictors of dyslexia highlighted in recent studies (e.g. from 2010-2019). After extensive research in Emerald, Frontier, sage, Science direct, Springer, Taylor& Francis, Wiley database, 59 articles met the inclusion criteria. We concluded that: phonological awareness (PA), rapid naming (RAN) and letter-knowledge (LK) are the most important predictors of dyslexia in a regular orthography.

Keywords: dyslexia, phonological awareness, rapid naming, predictor

Introduction

The question of predicting reading ability has been extensively studied, however, the variables that predict reading skills vary according to the theory on which they are based. The starting point of this systematic review is Wimmer and Schurz `s review (2010), the latest one that studies the dyslexic predictors in a language with regular orthography. The present paper includes 59 cross-sectional and longitudinal studies on populations with orthographies with different degrees of regularity, including 3 meta-analyses and 2 systematic reviews.

Dyslexia is a specific learning disorder characterized by reading difficulties that are not due to lack of adequate cognitive skills, motivation, access to education, and are not based on a sensory deficiency (Lyon, Shaywitz, & Shaywitz, 2003). The severity, incidence, and manifestation depend on the transparency of orthography, but it should also be mentioned that no language is immune to reading disorder (Katzir, Shaul, Breznitz, & Wolf, 2004).

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Phonological awareness and word reading efficiency

Most researchers identify phonological awareness (PA) as one of the most important predictors of dyslexia (Wagner & Torgesen, 1987). PA is the ability to detect and manipulate phonological units of different sizes (Thomson & Goswami, 2010). Specific tasks are sound identification, the synthesis of sound in words and syllables, substitution, addition, deletion, blending, rhyme identification and word segmentation (Munoz, Valenzuela, & Orellana, 2016; Wagner & Torgesen, 1987). The phonological skills deficient in dyslexic children are letter identification and differentiation, phoneme-sound association, phonological processing of information (Froyen, Willems, & Blomert, 2011). PA develops from age 3- or 4- (Phillips, Clancy-Menchetti, & Lonigan, 2008) and requires learning the principles of literacy (Sanchez, Magnan, & Ecalle, 2012).

The principles of literacy refer to the understanding that all written words are words spoken by a sound-to-sound correspondence. Sounds are represented by letters or groups of letters (Philips et al., 2008). The involvement of phonological and orthographic processes can be regarded as a continuous one: the reading of isolated words is more orthographic while the reading of pseudowords is rather phonological (Greenberg, Ehri, & Perin, 2002). PA accounts for 23% of reading efficiency from the beginning of schooling to the end of the second, then decreases to 4% at the end of the fourth class (Hogan, 2005, as cited in Park & Lombardino, 2013). Children, who in the fifth -grade exhibit weaknesses in PA and RAN, are most likely dyslexic (Park & Lombardino, 2013). According to some authors, the deficiency of PA does not disappear until the age of adolescence (Moura, Moreno, Pereira, & Simões, 2015), while others claim that the assessed children no longer have any problems of PA unless the tasks were more complex (Jong & van der Leij, 2003; as cited in Knoop-van Campen, Segers, & Verhoeven, 2018).

Rapid naming and word reading efficiency

Word reading is characterized by accuracy, speed, and prosody (Walczyk et al., 2007). A fluent reading allows the person to focus on understanding the text (Walczyk et al., 2007), and it increases with the ability to recognize the words (Norton & Wolf, 2012). Researchers have shown that PA is not the only important predictor of reading skills. Another important predictor is rapid naming (RAN), which refers to the cognitive processes involved in attaching a verbal tag to a visual stimulus (colour, object, digit or letter string (Gershwind, 1965; as cited in Wolf, Bowers, & Biddle, 2000).

Even though the name of the objects is learned faster, letters and digits are better automated by students (Norton & Wolf, 2012). The cognitive processes that are involved in RAN are attentional and visual: detection-discrimination - identification of the stimulus, integration of the visual features in the spelling and phonological representations; access and obtaining phonological labels, activation and semantic and conceptual integration of information, motor activation for articulation (Norton & Wolf, 2012). According to some authors, RAN is also a component of phonological processing, as it requires a phonological code, just like any other linguistic task (e.g. vocabulary) (Wolf et al., 2000), others claimed that is a process independent of phonological processing (Conrad & Levy, 2007; Georgiou, Torppa, Manolitsis, Lyytinen, & Parrila, 2012). There are children with high or low RAN with the same phonological ability (Conrad & Levy, 2007), and children with good PA and low RAN who also have dyslexia (Araújo, Pacheco, Faísca, Petersson, & Reis, 2010). Children with dyslexia need more time to name the items than those with normal development, regardless of the orthographic complexity of the language they speak (Landerl et al., 2019; Wolf et al., 2000; Conrad & Levy, 2007). The difference is maintained regardless of the type of the stimulus (alphanumeric or non-alphanumeric), indicating that other processes are involved in rapid naming than the reading of the letters (Araujo & Faisca, 2019).

Dyslexia in transparent orthographies

The etiological model for developmental disorders, like dyslexia, is multifactorial and probabilistic, and involves the interaction of multiple risk and protective factors, which factors alter the development of cognitive functions (Pennington et al., 2012). One of those factors is the phonological deficit, which may have auditory causes. According to Kuhl`s theory (2004), infants use prosodic and statistical patterns to detect phonemes and words in their native languages. So, reading skills development depends on the child`s language.

Children have limited perceptive and learning skills. Their perceptual abilities are influenced by both neurobiological heritage and the constraints of social space where they will learn their native language (Kuhl, 2004). Although the world's languages contain almost 66 consonants and 200 vowels, each language contains about 40 sounds, called phonemes (Kuhl, 2004). Learning how to read requires not only the identification of sounds but also the understanding of the alphabetical principle that links the sounds and letters (van Rijthoven, Kleemans, Segers & Verhoeven, 2018). A high regularity of spelling has a beneficial effect in the initial reading phase when children are confronted with many new words and they are based on the phonological principle for decoding (Wimmer & Schurz, 2010). Retaining letters sequences, which occur more frequently, allow spelling word recognition and rapid visual processing (Wimmer & Schurz, 2010). Although German children, like Romanian ones, do not learn letters from the kindergarten, at the end of the first grade their decoding skills are superior to those of Anglophones, which learn the letters much earlier (Mann & Wimmer, 2002). In more transparent orthographies, the accuracy of reading reaches the ceiling level after a few months of training, reading speed (fluency) remaining the only component that makes the difference between skilled readers and those with difficulties (Landerl & Wimmer, 2008; Layes, Lalonde, & Ribai, 2014). Children's fluency improves during school years, but those who have low abilities in first grade, in the eighth grade will still read slowly. Accuracy errors are generally limited to replacing a sound. RAN contributes significantly from first grade to eighth grade, but PA and short-term phonological memory (PSTM) only in first grade (Landerl & Wimmer, 2008). Interventions focused on PA and phonological decoding do not have any influence on fluency (Torgesen, Wagner, Rashotte, Herron, & Lindamood, 2010).

The role of RAN is more important in regular orthographies than in English (Araujo et al., 2010), while PA is determinant in irregular orthographies (Snowling & Hulme, 1994). Orthographic transparency modulates the predictors' contribution, still this transparency does not change the pattern (Ziegler et al., 2010). Cognitive development is universal, at least for alphabetic texts, and differences in orthographic transparency translate into the rate of reading development. Learning how to read is closely related to the phonological capabilities of the child, but also requires the visual form of letters to be retained, involving the visual memory process. Smaller children have the tendency to retain the illustrated information in visual form, in contrast to the older ones, who rather retain verbal information (Gathercole & Baddeley, 1993). The neurocognitive profile changes with age, but it seems that RAN and VSM visual-space memory can be used to predict dyslexia at the age of literacy for a transparent spelling language (Helland & Morken, 2016). Italian preschoolers have a developed syllable awareness, and after a few months of literacy, they reach a high-accuracy of word reading and pseudoword reading (Fastame, Cardis, & Callai, 2018; Zoccolotti, De Luca, Di Filippo, Judica, & Martelli, 2009) Romanian children with dyslexia presented not only low fluency but also low accuracy (David, Roşan, & Gavril, 2018). This result is not in line with researches on other transparent orthographies.

The current study: This review starts from that of Wimmer and Schurz (2010), who studied the effect of cognitive deficits responsible for dyslexia in a regular orthography and extends this study by highlighting other predictive factors for dyslexia. The present paper also includes the results of three meta-analyses, summing up their results, in order to explain the cognitive deficits responsible for dyslexia.

The objectives of the present study:

- Studying the differences in reading performance between students with dyslexia users of a high or low orthographic regularity of writing.
- identifying key predictors that should be considered for early discovery of a user's dyslexic child of a regular spelling.

Method

Search protocol

We used a search protocol according to Systematic Reviews (Popay et al., 2006). The protocol deals with the research question, search strategies, inclusion criteria, data collection and analysis procedure.

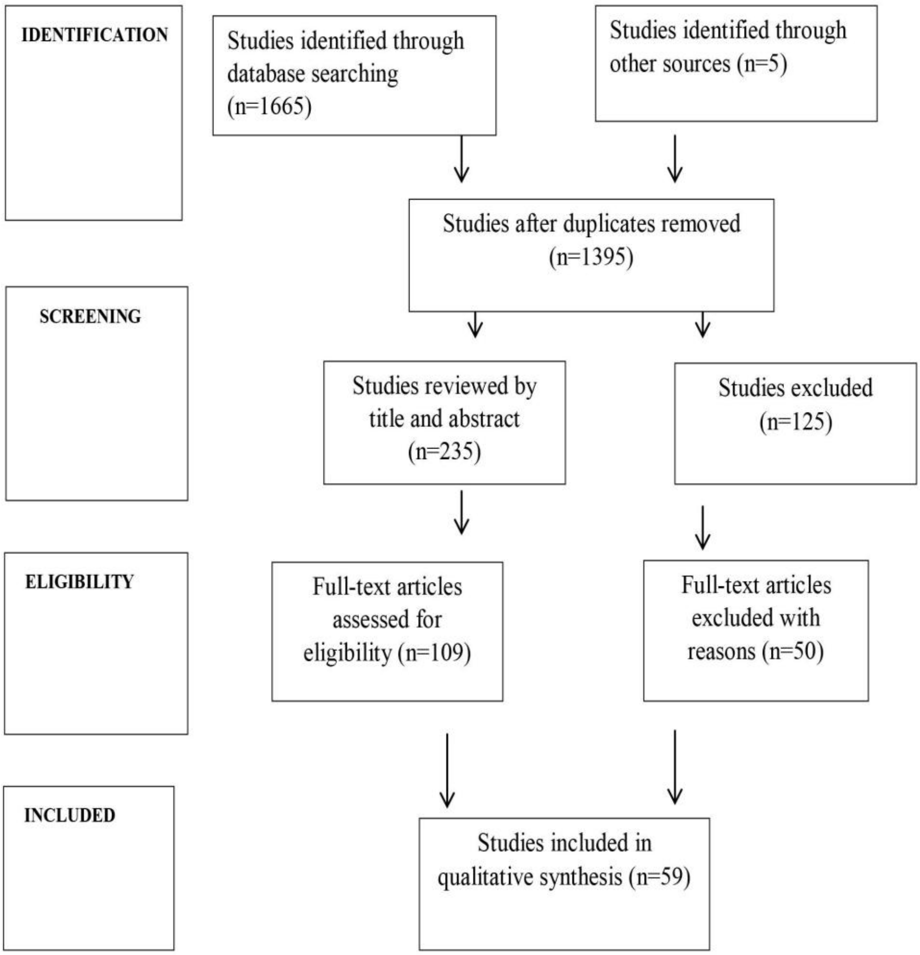

Figure 1. Selection of studies

Inclusion criteria

The included studies met the following conditions: 1. They were published between 2010 and 2019; 2. Are in English; 3. Refer to dyslexia or literacy and its predictors; 4. The participants are students from first to twelve grades.

Search procedures

Potential studies were identified after searching in the following databases: Emerald, Frontier, Sage, Science Direct, Springer, Taylor & Francis, Wiley. The terms of the search were used: dyslexia, predictor, PA. In the first phase, we included 234 articles, which refer to reading skills. 72 were removed by title for referring to comorbidities (ADHD, borderline, schizophrenia, Down syndrome, autism, etc.), to other dysfunctions: dyscalculia, hyperlexia, or for being in other languages than English. There are 163 articles left. We have removed another 53 because their abstract refers to other population samples (college students, preschoolers, adults), and some analyzed irrelevant aspects to research. 53 studies were removed by content, 59 articles remained.

Results

57 studies met the inclusion criteria. They are distributed as follows: 29 longitudinal studies, 24 cross-sectional 3 meta-analyses, 1 systematic review.

Wimmer and Schurz`s (2010) review encompass 2 longitudinal studies and more data obtained from their own laboratory. The participants were German children, who showed low fluency, but normal development at phonological abilities, working memory and visual attention. The data obtained do not support the phonological deficit theory. The authors conclude that the dysfunction is due to reduced orthographic – phonological connectivity. The following meta-analysis was conducted by Melby-Lervåg, Lyster, and Hulme (2012) studies with an extreme group and correlational studies with unselected samples. The results show the major role of phonemic awareness in the development of reading skills. This deficiency requires additional training for fluency development (Bowyer-Crane, et al., 2008). They claim that phonemic awareness deficits precede reading and have a causal role, being universal and independent of orthographic transparency. The other two phonological abilities: rhyme awareness and VSTM are correlated with individual differences (general non-verbal intelligence, vocabulary, etc). Zhang and McBride-Chang (2010) studied the role of auditory perception of reading skills. Auditory perceptions form the basis of PA and have an indirect role in reading skills development. The auditory perceptions role is mediated by speech perception. Peng, Wang, Tao, and Sun (2017) described the profile of Chinese children`s cognitive deficits. Chinese is an ideographic language, where morphological awareness plays an important role. The meta-analysis is based on 81 studies conducted on Chinese children. The results show that students with developmental dyslexia (DD) have severe deficits in morphological awareness (MA), orthographic knowledge (OK), PA, RAN, VSTM and motor skills (MS). RAN and OK seem to be the basis of deficiency.

Cross-sectional studies

We note that, in the majority of the cross- sectional studies most researchers found RAN and PA as powerful positive predictors for the development of reading abilities (Aguilar-Vafaie, Roshani, Hassanabadi, Masoudian, & Afruz, 2011; Aravena, Tijms, Snellings, & van der Molen, 2018; Bexkens, van den Wildenberg & Tijms, 2014; de Groot, van der Bos, van der Meulen & Minnaert, 2017; Fastame et al., 2018; Landerl et al., 2013; Moura et al., 2015; Rakhlin, Mourgues, Cardoso-Martins, Kornev, & Grigorenko, 2019; Soriano & Miranda, 2010; Soriano-Ferrer, Nievas-Cazorla, Sánchez-López, Félix-Mateo, & González-Torre, 2014; Talli, Sprenger-Charolles, & Stavrakaki, 2016; Tibi & Kirby, 2017; Tilanus, Segers, & Verhoeven, 2013; Tobia, Gabriele, & Marzocchi, 2013; Vaessen & Blomert, 2010).

PA and RAN have an independent effect on reading abilities, as evidenced by alternative control of predictors (Tibi & Kirby, 2017) and are mediators between students' semantic abilities and reading efficiency (van Rijthoven et al., 2018). The independent effect is also supported by identifying a group of students with low RAN; appropriate PA and who have dyslexia (Araujo et al., 2010).

Landerl et al. (2013) conducted research on children of 6 languages with different levels of transparency (Finnish, Hungarian, Dutch, German, French, English). They have concluded that phonemic awareness and RAN are strong concurrent predictors of dyslexia, and verbal skills have a minor role. The RAN / phonemic awareness impact is stronger in more opaque orthographies, reinforcing the idea that orthographies irregularity exacerbates dyslexic symptoms. Similarly using population from five different countries and languages (e.g. Finnish, Hungarian, Dutch, Portuguese, French), Ziegler et al., (2010) showed that PA is the most powerful predictor of reading, but its effect is modulated by the transparency of orthography as well as other predictors (e.g. vocabulary, short phonological memory). RAN has a mild fluctuating influence, this result probably being due to the subfactor used in the specific evaluation test: objects. For Portuguese, a language with semi-transparent orthography, PA is correlated with reading accuracy and RAN with fluency (Moura et al., 2014). The fact that PA's role decreases in languages with a more consistent orthography than English, leads to the idea that part of the influence of some predictors is taken over by orthography (Araujo et al., 2010); and VSTM, vocabulary and visual-spatial attention (Tobia et al., 2014).

Following RAN and PA, Blomert and Willems (2010) classified dyslexic children in 4 subgroups: those with reduced PA, those with reduced PA and LS (poor speech processing), then reduced RAN, low PA and a group at which PA, RAN is intact. Classification especially draws attention to the group of those who have incipient cognitive factors and yet read slowly and inaccurate. Their fluency is better than those in the other subgroups, and they are younger in age. These data suggest that the cognitive factors that lead to failure have not yet developed (Willems, Jansma, Blomert, & Vaessen, 2016)

The major positive predictive role of RAN for reading can be found in many studies (Araujo et al., 2010; Farukk & Vulchanova, 2014; Liao et al., 2015; Scheltinga, van der Leij, & Struiksma, 2010). Liao and his colleagues (2015) brought together the results of three different research conducted on Chinese children and concluded that RAN is positively associated with reading accuracy and only partially with fluency, as children have to access orthographic representations from the long-term memory for reading. RAN can be used together with pseudo-repetition for the detection of dyslexics in languages where there are no other measuring instruments for this purpose, such as Urdu (Farukh & Vulchanova, 2014).

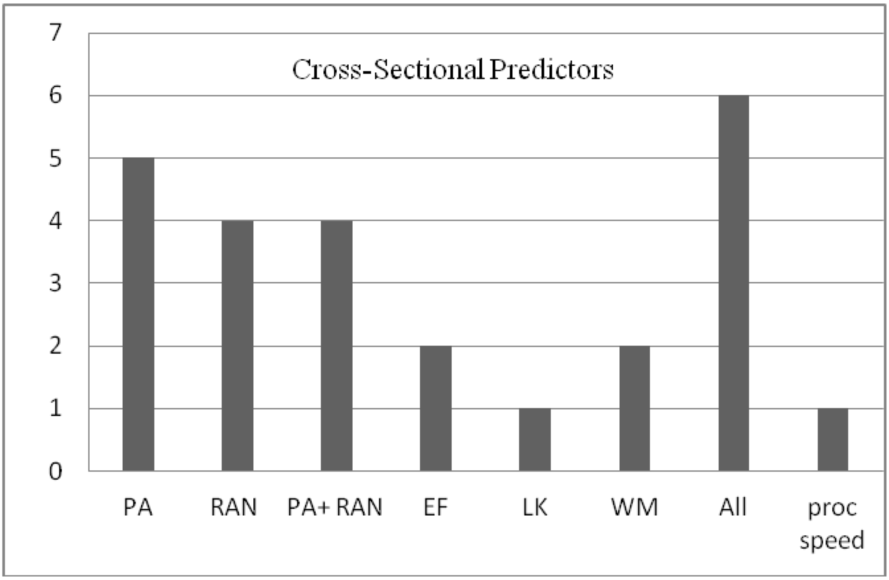

Figure 2. Cross-sectional studies`s histogram

RAN is also associated with phonological processing, processing speed, and interference control, the latter is not significantly correlated with reading skills. Children with dyslexia experience lower scores on phonological and reading skills, but not on inhibition control. This demonstrates that inhibition control is a cognitive mechanism involved in RAN but does not contribute to the impairment of dyslexic reading abilities (Bexkens et al., 2014).

The following studies highlight the major role of PA in reading skills (Knoop-van Campen et al., 2018; Layes et al., 2015; Law et al., 2018). PA mediates the relationship between reading efficiency and working memory and remains important for reading efficiency when children are older (Knoop-van Campen et al., 2018). Executive functions, which have been shown to contribute to reading performance are working memory, and switching attention, especially for children from a minority (Jacobson et al., 2017; Sanders, Berninger, & Abbott, 2018).

Table 1. Cross-sectional studies

Nr	Author	Year	N	Age	SD	Predictor	VD	Results
1	Aguilar-Vafae et al.	2011	60			PA, STM	WR, TR	PA, WM beyond RAN
2	Aravena et al.	2018	72	9.26 9.37	1.07 0.74	LSS id PA, RAN	R artificial WR	PA, RAN
3	Bexkens et al.	2014	86	10	1.02	PA, RAN PM, Voc GPS, MC IC	WR, TR accuracy rate	RAN alphanumeric
4	de Groot et al.	2017	1,262	10.05	1.83	PA RAN NWR	fluency Wrec	PA, RAN
5	Fastame et al.	2018	54	8.75 9.59 10.66		VSTM PA NWR	TR, WR spelling	PA
6	Farukh & Vulchanova	2014	160	160		RAN NWR	fluency accuracy	RAN fluency NWR accur
7	Jacobson et al.	2017	761	11.74	2.11	Voc, PP RAN, probl. Solv FR M	WR fluency compreh	EF for fluency WM for fluency, acc AS fluency, TR
8	Kim, Park, & Lombardino	2015	61	7.42	0.6	RAN	W rec	RAN

Nr	Author	Year	N	Age	SD	Predictor	VD	Results
							fluency	alphanumeric
	Knoop							
9	van	2018	613	9.1	7.41	PA	WR	PA indirect
	Campen							Mediator
	et al.					WM		WR-WM
10	Layes	2015	53	9,8		PA	WR	subgrups
	el al.			9,1		NWR		identif
						RAN,		
11	Liao	2015	284	8.15	3.58	PAL	character	RAN accuracy
								partial for
	et al.					OP	rec rate	fluency
								PA accur,
12	Moura	2014	72		1.42	PA, RAN	WR	fluency
	et al.					VSTM	fluency	RAN fluency
13	Park &	2013	65			PA	WR	PA >PA younger
	Lombardino		28	7.8		RAN	TR	PA younger
			35	12.5		Vis Match		
								PA for OC,
14	Rakhlin	2019	96	13.73	0.88	PA	WR	NWR
	et al.					RAN	spelling	RAN fluency
						NWR	OC	
				10;11;	.33;.6			WM compr,
15	Sanders	2018	103	12	1	voc, PP,	WR acc,	fluency
	et al.			13;14	0.6	RAN,	fluency	Probl sol, compr
						Probl		
						solv	compreh	EF for reading
						FRM		
	Soriano							
	&					RAN,		
16	Miranda	2010	82	9.9	1.5	WM	WR Acc	low acc, fluency
						PSTM,		
						PhA	fluency	low RAN, PhA
								WM, PSTM
17	Soriano-	2014	80	11.2	1.4	VWM	WR	lower PhA
	Ferrer					PSTM	compreh	PSTM, RAN
						PhA,		
	et al.					RAN		VWM
						NWR		
						PhA,		
18	Talli	2016	15	9.22	0.52	RAN	WR	SLI lower
	et al.		15	9.23	0.63	PSTM	Allouette	than DD
			30	9.175	0.54			in compr
			154	7.27	0.32			PSTM,PhA
19	Tilanus	2013	230	6.99	0.48	PA, RAN	W decod	PA to W decod
	et al.					WM, LK	NW decod	accur
								LK letter
						ID		dictation
								ID spelling
20	Tobia	2014	651			Voc, PA	TR	PA, RAN
	et al.		114	7		Vis atten		younger

Nr	Author	Year	N	Age	SD	Predictor	VD	Results
			114	8		VSTM		voc, VSTM,
			198	9		vis search		vis atten
			121	10		vis recall		older
						RAN		
			142					PA, RAN all
21	Vaessen	2010	3	7.27	0.41	RAN	WR	word
	et al.			7.84	0.425	BRT		types
				8.98	0.45	Voc		PA to NW
				9.8	0.47	NWR		RAN to WR
				11.13	0.49			
				12.13	0.47			
			224			PA,		
22	Vaessen &	2013	4	7.57	0.42	NWR	WR	PA, RAN
	Blomert			8.13	1.35	RAN		LK fluency
								RAN increased
				9.08	1.375	BRT		age
						LK,		LK, PA
				10.02	1.65	VWM		decreased
23	Willems	2016	334		0.99	FR, PA	fluency	four subtypes
						RAN,		
	et al.		134	8		NWR	WR	reading impaired
			111	9		LSS proc		general impaired
								PA-RAN poor
			89	10		VWM		read
								PA-LS poor
						Rec voc		reads
						BRT		
			126					
24	Ziegler	2010	5			PA	WR	PA decoding
			Fin					
	et al.		166	8.96	0.35	RAN	decoding	RAN fluency
			French					
			18	7.7	0.51	PSTM		PSTM accuracy
			Hun					
			139	8.83	0.53	Voc		Voc, WR Finland
			Dutch					
			597	7.78	0.44			fluency France

Notes. PA - phonological awareness, WM - work memory, STM - short term memory, WRE - word reading efficiency, GP - graphemic-phonemic learning, LSSI AO - letter speech sound identification in an artificial orthography, LS - letter-speech sound mapping deficit, EF - executive functions, BRT - baseline response time, WR - word reading, NWR – pseudoword / nonword reading, W - words, PW - pseudowords, TR - text reading, CD - cognitive deficits, GPS - general processing speed, MC - motor control, IC - interference control, VA - verbal abilities, Wrec - word recognising, CLT - cognitive-linguistic translation, AS - attention switching, FRM - fluid reasoning memory, OC - orthographic choice, LK - letter knowledge.

Longitudinal studies

Most research (14) that tested both PA and RAN, highlighted their major role in the development of reading skills (Aravena et al., 2018; Caravolas et al., 2012; Carroll, Solity, & Shapiro, 2016; Dandache, Wouters, & Ghesquière, 2014; Eklund, Torppa, Sulkunen, Niemi, & Ahonen, 2018; Fricke, Szczerbinski, Fox-Boyer, & Stackhouse, 2016; Helland & Morken, 2016; Landerl et al., 2019; Moll et al, 2016; Nevo & Bar-Kochva, 2015; Poulsen & Elbro, 2018; Schaars, Segers, & Verhoeven, 2017; Thompson et al., 2015; Torppa, Lyytinen, Erskine, Eklund, & Lyyntinen, 2010).

Landerl et al. (2019) studied the PA and RAN effect for 5 languages with different levels of transparency (English, German, Dutch, French, and Greek). They were not able to highlight a general pattern, but RAN was a predictor of fluency in all languages, while PA depends on the degree of regularity of orthography, the difficulty of the task, the development level of the participants. Similar research conducted by Georgiou et al. (2012) in 3 different languages (English, Greek, and Finnish), highlights the fact that reading skills depend on the degree of transparency of languages. LK and RAN correlated significantly for all languages, while PA correlated for Greek and English decoding. This reinforces the universality of RAN and PA`s dependency on orthography.

On a parallel between Norwegian and Australian English one regular and the other irregular), PA is a predictor in first grade and remains significant for English speakers, and RAN is a universal predictor for both orthographies (Furnes & Samuelsson, 2010). Bigozzi, Tarchi, Pezzica, and Pinto (2016) found that only OK is a predictor in Italian samples. I mention that they only measured PA and OK. For Slavic languages, the origin of dyslexia is an impairment of phonological skills: PA, RAN, LK, vocabulary, and PSTM (Moll et al., 2016). RAN appears as a precursor of reading abilities in native languages, PA for foreign languages (Helland & Morken, 2015).

The PA / RAN effect is variable over time, PA is more important in primary school, then decreases its effect due to the reading experience and increases the RAN effect (Vaessen & Blomert, 2010). This switching is more pronounced for high -frequency words.

The presence of speech sound disorders (SSD) can lead to phonemic awareness disorder, thus indirectly has a small but significant contribution to the development of speech abilities (Hayiou-Thomas, Carroll, Leavett, Hulme, & Snowling. 2017; Moll et al., 2016). However, the severity of the SSD is not a significant indicator of reading abilities. If SSD is accompanied by language disorder, the latter leads to difficulties in the learning process.

Family risk (FR) aggravates dyslexia`s symptoms, as Pennington (2006), showed. This once again supports Pennington's theory (2006), pointing out that multiple deficits lead to aggravation of dyslexia (Hayiou-Thomas, Carroll, Leavett, Hulme, & Snowling., 2017). Speech perception at 5 ½ years correlates with language, attention, RAN, phonemic awareness. The indirect effect on the reading abilities through phonemic awareness is insignificant, suggesting that its effect on the lexicon is independent (Snowling, Lervag, Nash, & Hulme, 2019). In contrast, FR is a stronger predictor for dyslexia than an underdeveloped language in the pre-school period (Thompson et al., 2015). Children with FR had lower reading abilities than normally developed children (Blomert & Willems, 2010), indicating that dyslexia should be considered as a continuum (Dandache et al, 2014). FR is a predictor for fluency and PISA reading (Program for International Student Assessment; Eklund et al., 2018).

The major role of PA came from the following studies: Hulme, Zhou, Tong, Lervåg, and Burgoyne (2019); Nithart et al. (2011); Schwenck, Dummert, Endlich, & Schneider (2015); Tamboer, Vorst, and Oort (2016); van Kampen, Segers, & Verhoeven (2018b). In these studies, RAN wasn`t tested.

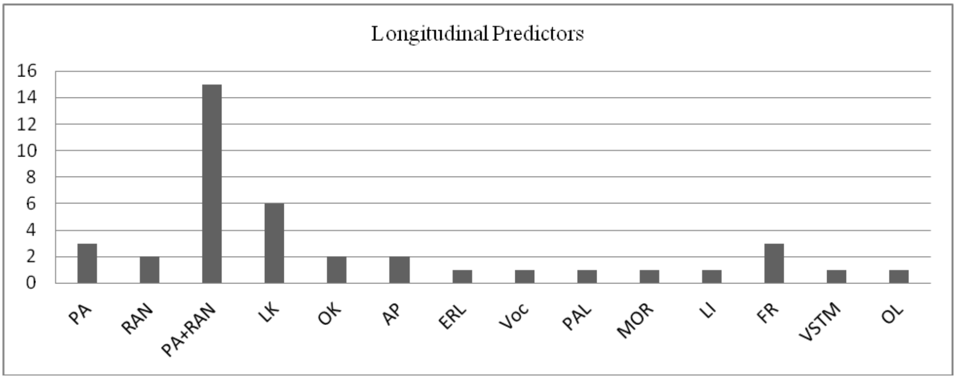

Figure 3. Longitudinal studies `s histogram

We can distinguish dyslexic children from children with dyscalculia using PA tests (Schwenck et al., 2014), and the correlation between working memory and reading efficiency is mediated by PA (Knoop-van Campen et al., 2018). PA measured by the end of the preschool -years and the VSTM at the end of the first grade predicts reading efficiency (Nithart et al., 2011). Also, the rise time (auditory ability subfactor, is the rate of change of the amplitude envelope at onset; Thomson & Goswami, 2010) measured at the end of the kindergarten is a predictor for PA. Language disorders are precursors of coding abilities (phonemic awareness, LK, and RAN), which in turn predict dyslexia (Moll et al., 2016). RAN is the only risk marker compared to PSTM, OK and LK (Scheltinga et al., 2010).

In ideogram writing there are positive cognitive processes in ideogram writing, like: semantic skills (e.g. vocabulary), visual discrimination and PA.

The visual discrimination and PA don t have this property for alphabetical writing (Hulme et al., 2019). Tong, McBride, Lo, and Shu (2017) additionally add RAN and (MA) as predictors.

The family environment can indirectly influence reading skills. As the results of a study show, parental education is a positive predictor for PA, and the number of books read with the parents for RAN (Inoue, Georgiou, Parrila, & Kirby, 2018).

Table 2. Data from longitudinal studies

Nr	Name	Year	N	Age	SD	Predictor	VD	Time	Results
1	Bigozzi et al.	2016	642	4.98	0.31	PA concept writing system	TR compet	4	OK
2	Blomert & Willems	2010	92	5.8	4.9	PA, PLP LSSI PWM, LK LSSD	WR NWR	1	FR
3	Caravolas et al.	2012	235	5.02 5.95		PhA RAN LK	Lwriting w spelling w to picture matching	0.83	RAN nonal PhA LK
4	Carroll et al.	2016	267	4.5		PA, RAN LK, AP VSTM VA, MB MS, Voc S prod	WR	4	PA
5	Dandache et al.	2014	62	6;7 9;15		PA, LK, RAN VSTM	WR, NWR spelling	6	PA RAN
6	Eklund et al.	2018	158	2,5 to 15		PA, RAN LK FR	PISA R fluency		PA, RAN, FR
7	Fricke et al.	2015	78	5.11		PA, LK, RAN, OL	spelling compreh WR, NWR	2	LK, RAN PA
8	Furnes & Samuelsson	2014	2006	4.83 5.08	0.01 0.14	LK, RAN VM, PA SSS	WR	2	PA cgrade 1 Skandinav PA to English RAN to all orthography
9	Georgiou et al.	2012	240	5.5		PA, LK, RAN	NWR, TR spelling	2	LK
10	Hayiou-Thomas et al.	2017	68	3.6	3.13	SSD LI	PA, compr spelling WR	3	LI FR
11	Helland &	2015	120	5 to		PA, STM	L1, L2	6	VSM, RAN

Nr	Name	Year	N	Age	SD	Predictor	VD	Time	Results
	Morken			11		WM, VS RAN VL, Voc	WR translate writing dictation compreh		for L1 PA to L2
12	Hulme et al.	2019	143	7.1		PA, Mc Vis M VD, RAN Voc, Mc TC, Vis D	WR spelling	2	Voc PA Vis D
13	Inoue et al.	2018	214	5.6	0.32	PA, RAN PM, OK	WR spelling	0.5	PA hiragana RAN, MA
14	Knoop-van Campen et al.	2018	50 615	9,1 9,5		WM PA MA	WR		Pa mediator WM to WR kanji
15	Landerl et al.	2019	1120	7		PA, RAN	fluency	2	RAN
16	Law et al.	2017	44	4.5		LK, PA, AP	NWR, WR fluency	2	AP FR
17	Moll et al.	2016	308	5.52		PA, LK RAN, PM grammar Voc	WR spelling	1	RAN, Lk Voc, PM
18	Nevo & Bar-Kochva	2019	70	6;7;8	3.65	PA, RAN PS	NWR, WR spelling	2	RAN
19	Poulsen & Ebro	2018	137	6		RAN, LK, PA,	W aloud compreh WD fluency	5	PAL controlled PA RAN, Lk
20	van Rijthoven et al.	2018	663	8.55	1.05 1	PA VWM	WDE NWDE	4	PA mediates VWM, WR
21	Sanchez et al.	2011	123	5.66		W struct.K PhA, MA LK, OK	WR spelling	1	Lk PhA
22	Schars et al.	2017	146	6.2	0.4	Voc, PhA VSTM, RAN Vis STM	WD	1	PhA RAN
23	Schetltinga et al.	2010	122	7.93	7.8	RAN	fluency	0.5	RAN
24	Schwenck et al.	2015	929	8		PWM vis spat WM CEWM PA inattention NR compet	compreh spelling math skills	2	PA protectiv e factor

Nr	Name	Year	N	Age	SD	Predictor	VD	Time	Results
25	Snowling et al.	2017	237	5.6		SP, RAN PhA, Voc Gr, CP, A	WR spelling	3	RAN
26	Thompson et al	2015	260	3.5		PA, RAN ES, W NW rep LM, LK	WR spelling	4	PA, ES Lk RAN FR at 8
27	Tong et al.	2017	164	6;7;8		RAN, PA MA	WR spelling	3	MA RAN
28	Torppa et al.	2018	158	2 to 15		PA, RAN LK, FR, M p sens	NW, TR spelling		PA, RAN LK Morphology
29	Varvooren, Poelmans, de Vos, Ghesquière, & Wouters	2017	87	5.16	3	ATP, PA RAN, LK SPIN Intens discr RT discr FM detec	WR NWR	5.17	SPIN for PA PA mediator for WR

Notes. PA - phonological awareness, PhA phonemic awareness, RAN - rapid automatic naming, Kg - kindergarten, PS - processing speed, OK - orthographic knowledge, AP - auditory processing, LK - letter knowledge, STM - short-term memory, FR - family risk, PWM - phonological work memory, Voc - vocabulary, LI - language impairment, Vis STM - visual STM, SP - speech perception, VSTM - verbal short term memory, LSSI - letter- speech sound identification, LSSD - letter-speech sound discrimination, PLP - phonological lexical processing, MS - motor skills, SSD - speech sound disorder, WR - word reading, NWR - nonword reading, WD - word decoding, VS - visuospatial skills, VL - verbal learning, L1 - native language, L2 – English, VSR - visuospatial recall, WRA - word reading accuracy, Gr - grammar, PPD - perceptual phonological discrimination, LA - lexical abilities, W Rec - word recognition, LR - lexical retrieval, PS - phonological speed, A - attention, CP - categorical perception, LM - language measures, W NW - word, nonword repetition, ES - executive skills, TR - text reading, NWTR - nonword text reading, EL / RL - expresive language, receptive language, P sens - phonological sensitivity, MC - morphological construction, VD - visual discrimination, Vis M - visual memory, TD - tone discrimination, OL - oral language.

Discussion

The disorders that occurred in the literacy process are in the attention of researchers all over the world. Several subprocesses have been identified for their contribution to reading learning: PA, RAN, WM, LK, etc. These should be evaluated at pre-school age in order to be able to take the most effective measures to combat dyslexia. The majority of both longitudinal and cross-sectional studies confirm that PA and RAN are major predictors (Bexkens et al., 2014; Carroll et al., 2016; Dandache et al., 2014; Landerl et al., 2019; Moura et al., 2014; Tibi & Kirby, 2017; Thompson et al., 2015; van Rijthoven et al., 2018). Their impact is stronger in opaque orthographies than in the transparent ones (Furnes & Samuelsson, 2010; Landerl et al., 2013; Ziegler et al., 2010). In addition, gravity and prevalence are lower in languages with irregular orthographies (Mann & Wimmer, 2002). For Romanian children, it is important to see what are the major contributing factors in languages with regular orthographies (David, Roşan, & Gavril, 2018).

In our brains, we develop a single reading network where word access is influenced by word frequency and reading experience (Vaessen & Blomert, 2010). According to Kuhl`s theory (2004), it must be considered if the evaluation is in the children`s native language (Helland & Morken, 2015; Zhang & McBride-Chang, 2010).

The effect of the two predictors is independent, there are dyslexic children with low RAN and high PA (Araujo et al., 2010), respectively small PA and high RAN (Layes et al., 2015). Compared with children with ND, those with FR have lower scores for all cognitive processes tested, and children with FR are superior to those with DD (Caravolas et al., 2012; Dandache et al., 2014, Moura et al., 2014; Soriano-Ferrer et al., 2014; Torppa et al., 2010; Vaessen & Blomert, 2013). Some researchers believe that these are signs of a language disorder, or a coding deficiency (Moll et al., 2016). PA is the predictor of accuracy in irregular orthographies and its impact decreases in the regular ones (Furnes & Samuelsson, 2010; Landerl & Wimmer, 2008; Ziegler et al., 2010), and decreases with age, while increasing the effect RAN, predicting fluency (Landerl & Wimmer, 2008; Tobia & Marzocchi, 2014; Vaessen et al., 2010).

PA has a contribution to the development of the vocabulary (Hulme et al., 2019). Linguistic and non-linguistic processing speed along with PA is a strong predictor for younger children (Tobia et al., 2014). With the growth of children, it increases the impact of the vocabulary, short-term verbal memory and visual attention (Tobia et al., 2014; Park & Lombardino, 2013).

Adults with DD with more fluent, less severe RAN deficiency, who have received educational support, have an increase in fluency, however in working memory, processing speed, verbal skills still have lower scores than ND adults (Aro et al., 2019). They use orthographic or visual processes to read while children use phonological processes (Greenberg et al., 2002). The RAN effect is lower in studies that used nonalphanumeric subfactor in testing reading efficency (Carroll et al., 2016; Kim et al., 2015), PA is lower for those who tested rhyme / syllable awareness or had longer measurement times (Høien, Lundberg, Stanovich & Bjaalid, 1995; Fricke et al., 2016). The attempt to classify dyslexia is not conclusive: Willems and his collegues (2016) identified 4 subgroups based on observed dysfunctions, but other research does not reveal the clear delineation of subgroups (Carroll, 2016; Tamboer et al., 2016). Various cognitive dysfunctions support Pennington`s (2006) theory of multiple dysfunctions (Ruffino et al, 2010) meaning that dyslexia is based on dysfunctions of several cognitive processes. The factors contributing to PA development are: speech perception in noise (Vanvoorenet al., 2017), preschooler`s speech disorders (Hayiou-Thomas et al., 2017), and the environmental factors (e.g. parents educational level and parental education, (Esmaeeli, Kyle. & Lundetræ, 2019; Liu & Georgiou, 2017). PA is a protective factor for children with IQ above average (Schwenck et al., 2014). RAN development contributes to phonological processing, processing speed, and interference control. The latter does not affect reading skills (Bexkens et al., 2015). Parental education also plays an important role in the development of phonological knowledge and phonology, and reading children's books on the development of RAN and vocabulary (Inue et al., 2018). Phonological and RAN tests allow us to differentiate dyslexics from those with dyscalculia (Schwenck et al., 2014), from those with ADHD (de Groot et al., 2017), because children with DD score lower scores than those with dyscalculia or ADHD. Children with speech disorder impairment (SLI) have similar scores in decoding and fluency skills, and weaker than DD in comprehension (Talli et al., 2016). Working memory and semantics have a PA mediated effect on reading skills (Knoop-van Campen et al., 2018; van Rijthoven et al., 2018). Some studies show that LK is the strongest predictor of literacy, even for an artificial script (Aravena et al., 2018). This indicates that a child testing for LK should be considered in addition to PA and RAN. In dyslexic children, however, even after several years of instruction, automation of the process of integration of letter recognition does not take place (Froyen et al., 2011). Vocabulary and grammar knowledge proved to be very important for word recognition and comprehension (Fricke et al., 2016). OK along with RAN explains some of the variances of decoding abilities, as both are based on processes of accessing long-term orthographical representations (Liao et al., 2015). This access is sufficient for an accurate reading, but not for fluency, which needs parafoveal processing (Liao et al., 2015). One thing that experienced teachers have noted is that the best predictor of second-reading reading is first class reading, which in turn is predicted by pre-school skills (Fricke et al., 2016). This highlights once again the need to start formal training for PA at a younger age (Fricke et al., 2016). For English spelling PA is an important predictor (Treiman, Kessler, & Caravolas, 2019). Executive functions, especially commutative attention, can contribute to the differentiation of dyscalculia form dyslexia, it has a role in learning to read minority children by switching from one language to another (Jacobson et al., 2017). Phonological instruction received in one language translates phonological skills into the other studied languages (Goldenberg et al., 2014).

Conclusions

To get an overview of Romanian dyslexics, an analysis of PA, RAN, LK should be tested (Park & Lombardino, 2013; David, Rosan & Gavril, 2018). It is also important for children to attend kindergarten (Fricke et al., 2015). In the kindergarten program there should be PA development exercises (Munoz et al., 2018). At parents meetings, the importance of the quality time spent by parents with their children should be emphasized by reading books, telling them stories (Liu & Georgiou, 2017). Parents can`t be replaced *by gadgets*. It is important to ensure that articulation disorders do not turn into SSD because speech disorder plays a significant role in the occurrence of dyslexia (Hayiou-Thomas et al., 2017).

Limitations

We weren`t able to find studies from the gray zone while writing this review. These would provide a more complete picture of dyslexia. Also, we had access to only one study about the Romanian children. For future researches to determine important predictors for a Romanian population, PA, RAN, LK, and OK must be considered.

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