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Assessing oral word reading ability in Serbian speakers with acquired aphasia

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ABSTRACT

Difficulty reading single words represents a common sequel of acquired neurological injury and common component in aphasic breakdown. Investigation of reading disturbances in Serbian speakers with aphasia has been hampered by lack of any standardised clinical test. We report the development of the Serbian Word Reading Test (SWRT). This first clinical single word assessment for the Serbian language examines reading aloud words from different word classes (concrete and abstract nouns, verbs, adjectives, function words and non-words) and summarises performance based on error types (articulatory, phonological, semantic, neologistic, morphological, visual). Initial piloting with 51 people with aphasia after stroke and 50 control participants without neurological disturbance demonstrated high specificity (0.96) and sensitivity (0.98) for detecting presence of reading impairment. Preliminary comparisons between different aphasic syndromes evidenced contrasting success across varying word-classes. Analyses demonstrated significant differences in susceptibility to different reading errors according to aphasia subtype. Cross-language comparisons show largely similar profiles of breakdown to other languages despite the differing morphological and orthographic characteristics of Serbian. We present the SWRT as a valid and reliable clinical and research tool.

Keywords:

Reading, Aphasia, Serbian, Assessment

1. Introduction

Acquired disorders of reading (also termed acquired alexia or dyslexia) pose a significant problem for many people after stroke or other central nervous system damage (Brookshire, Wilson, Nadeau, Rothi, & Kendall, 2014; Coslett & Turkeltaub, 2016; Knoll- man-Porter et al., 2019; Vukovi´c, Vukovi´c, & Miller, 2016). They arise from left and right hemisphere disruption. Right-hemisphere lesions typically lead to alexia associated with visuospatial (dys)functions whilst left hemisphere lesions are commonly related to aphasic language impairment. This lends the study of alexia in left hemispheric lesions a special significance, from aphasiological and psycholinguistic aspects, but also in relation to patient rehabilitation.

Various models of word reading have been proposed to predict and account for reading derailments found amongst people with aphasia. Earlier perspectives (Ellis, 1993; Hillis & Caramazza, 1992) distinguished two broad routes to reading aloud – a lexical route dealing with whole words and a non-lexical path centred on sub-lexical graphemes and phonemes.

The lexical route presented two possible pathways: a direct lexical-semantic route from an orthographic input lexicon (where letter strings were linked to lexical entries), via semantics, to a phonological output lexicon and thence to spoken words; and a route directly from an orthographic input lexicon that bypassed semantics (hence precluding silent reading for meaning) and proceeded directly to the phonological output lexicon. Characteristic error types were posited to be associated with breakdowns in the different routes. Readers with intact orthographic input and phonological output lexicons but no access to semantics would be able to read words but without understanding what they meant. Once they hear what they have read they may be able to comprehend via auditory input. Routing via semantics would permit reading comprehension proportional to semantic system viability, but may contain semantic paraphasic slips - e.g. <car> is read as <bus>.

The non-lexical route linked directly from letter analysis to phonological assembly, via a grapheme to phoneme conversion process. This also bypassed semantics. Thus someone might not understand what they had read until they sounded it out aloud using ortho- graphic correspondence rules. This non-lexical route functioned optimally if the correspondence between letters and phonemes in a language was transparent (as is true of Serbian). In languages with opaque, variable letter to sound correspondence a person with this socalled surface dyslexia might misread the English word <yacht> as/jatʃt/or the French word <plaît> as/plait/. That is, they produce sound based errors as opposed to the semantic paraphasic slips of the lexical-semantic route. For similar reasons people with surface dyslexia struggle with homophone judgement tasks, deciding whether orthographic word pairs such as <pear-pair> in English, or <cette-sept> in French sound the same or not.

More recently views on the neuropsychology of reading have favoured connectionist, interactive models over the earlier serial, discrete point, rule governed conceptualisations. The primary systems perspective views reading as superimposed on or emerging from more generalised and phylogenetically older language circuitry and processes (Plaut, McClelland, Seidenberg, & Patterson, 1996; Rapcsak et al., 2009; Woollams, 2014). The approach stresses interaction between and integration of primary language systems such as semantics and phonology, as well as support from visual, attentional, mnestic and motor functions. The relationship is expressed in a triangle of interacting nodes subserving vision, phonology and semantics (Hoffman, Lambon Ralph, & Woollams, 2015; Madden et al., 2018; Neudorf, Ekstrand, Kress, Neufeldt, & Borowsky, 2019). On viewing a written word information flows multi-directionally be- tween visual, orthographic, semantic and phonological processing. Activation of a target word emerges when analyses from all sources resonate in harmony to cause the target word to win out over competing candidates.

This arises since within connectionist frameworks ‘knowledge’ is graded through probabilistic experience of what sequences of letters occur, what lexical items and meanings they are likely linked to and what sound patterns are associated with these letter strings and lexical items. Individual differences or biases in susceptibility to different manifestations of (acquired) dyslexia are thus linked to variation in the challenges posed by particular words (e.g. imageability, frequency, orthographic or phonological neighbourhood density, regularity, lexicality, morphology) and individual abilities in phonological processing, strength of connections in phoneme- grapheme activation and reliance on or access to semantics (Binder et al., 2016; Boukrina, Barrett, Alexander, Yao, & Graves, 2015; Boukrina, Barrett, & Graves, 2019; Dickens et al., 2019; Hoffman et al., 2015; Madden et al., 2018; Meteyard, Stoppard, Snudden, Cappa, & Vigliocco, 2015; Minkina, Martin, Spencer, & Kendall, 2018; Rimikis & Buchwald, 2019; Savill, Cornelissen, Whiteley, Woollams, & Jefferies, 2019; Woollams, 2014; Woollams, Lambon Ralph, Madrid, & Patterson, 2016).

Thus, whilst each of the points of the triangle delivers a unique contribution to reading success, and therefore ‘pure’ forms of visual, semantic or phonological dyslexia might occur if these nodes become selectively disordered, and whilst there may be dedicated processes for translating print into sound, because of the interactive/emergent nature of activation, misreadings may reflect biases or compensatory processes across the network and individual differences in reading experience and skills. For instance, in deciding whether <ost> in English is pronounced/ost/or/əʊst/in <cost> versus <post> words that have stronger semantic activation because of their higher frequency, imageability or iconicity (Meteyard et al., 2015) may be easier to resolve and therefore read correctly compared to where visual or semantic support is more difficult to activate. Further, since the primary systems view believes reading skills are predicated on more general visual, meaning and phonological processing, then one would expect dysfunction in tasks outside of reading to accompany dyslexic impairment, in e.g. visual processing of non-orthographic stimuli, or on phonological tasks that do not involve written words.

Lesions associated with acquired reading problems reflect this multimodal, multisystem nature of the reading task. Visual cortex (specifically left ventral occipito-temporal cortex) is implicated, but so also are interacting but dissociable streams supporting phonological (left pre-motor cortex, frontal-temporal perisylvian regions), semantic anterior temporal lobe) and motor processing in locations distributed across the dominant hemisphere and pathways between them (Boukrina et al., 2015, 2019; Cattinelli, Borghese, Gallucci, & Paulesu, 2013; Dickens et al., 2019; Dreyer & Pulvermuller, 2018; Neudorf et al., 2019; Pillay et al., 2018; Yu et al., 2018). Dickens et al., 2019 suggested highly specific loci within the networks activated differentially when processing challenges particular lexical or sound processes in reading - ventral precentral gyrus for reading pseudowords; planum temporale, supramarginal gyrus, ventral precentral and postcentral gyri and insula for reading regular words; pars orbitalis and pars triangularis for concrete words.

Where highly specialised streams exist it suggests specific reading deficits may arise from lesions confined to that pathway, thereby producing what appear to be 'pure' errors of phonology, semantics or visual processing. However, the interconnectivity also offers the opportunity for a variety of compensatory re-routings. In this case one might expect derailments deriving from interaction of visual, semantic and so forth variables. For instance, a speaker may produce/fa:kɪŋ naɪf/for < carving knife> from phonological interference, or < leaning towards > read as < leaning tower> from a combination of visual similarity and precedence of 'tower' over 'towards' in semantic associations for this speaker; they may successfully produce a word through e.g. recourse to compensation from semantic input to outweigh shortcomings in phonology. In the latter case responses may be correct, meaning any underlying dyslexia is detectable more through hesitation and response-time metrics than item accuracy.

Clinically, reading ability is typically assessed on the basis of subtests of standardised assessments for aphasia (e.g. Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1972); Western Aphasia Battery-WAB (Kertesz, 1982); Aachen Aphasia Test (Henseler, Regenbrecht, & Obrig, 2014; Miller, Willmes, & Bleser, 2000). The Gray Oral Reading Tests cover both expression (rate, accuracy, fluency) and comprehension (Wiederholt & Bryant, 1992). Batteries targeting more specific variables (word length; imageability; word frequency; non-words; and so forth) affecting reading have been devised – e.g., Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Kay, Lesser, & Coltheart, 1992), the Reading Comprehension Battery for Aphasia (La

Pointe & Horner, 1998), Woodcock-Johnson III Diagnostic Reading Battery (Woodcock, Mather, & Schrank, 2004).

The latter batteries offer a mixture of subtests designed to tease out effects on reading success of word length (number of letters; number of sounds in words) and complexity (e.g. presence or not of consonant clusters), spelling regularity, word frequency, gram- matical word-class, imageability/ concrete versus abstract words, lexicality (word-non-word) and visual (dis)similarity. Typically batteries include subtests of spoken word/sentence versus written word/sentence to picture and/or word matching. Functional reading (e.g. street signs), paragraph comprehension, and literal versus inferential comprehension are features of some tests. Some batteries include subtests of sound awareness and reading fluency. Most batteries do not provide a dedicated reading discourse comprehension section. Some assess only comprehension, some only output, none is comprehensive in covering all possible comprehension and expression variables. The SWRT (full details below) relies on reading aloud of single words differing in grammatical class, concreteness, and lexicality.

Whilst adaptations of English language tests into Serbian exist, such as the Serbian BDAE (Vukovi ́c, 2015), the systematic clinical assessment and study of acquired dyslexia in Serbian speakers has been hampered through lack of a standardised, validated test devised specifically for the Serbian language. Indeed clinical aphasiological studies of Serbian are practically non-existent (Vukovi ́c et al., 2016). Investigations of reading in Serbian speakers that have been reported have typically focused on characteristics of Serbian orthography and morphology to address issues in psycholinguistics rather than clinical matters (Durdevic, Milin, & Feldman, 2013; Havelka, Bowers, & Jankovic, 2006; Havelka & Rastle, 2005; Progovac et al., 2018; Rastle, Havelka, Wydell, Coltheart, & Besner, 2009; Vejnovic & Jovanovic, 2012). These do not offer a comprehensive view of reading and/or breakdown in Serbian and so cannot support issues of clinical differential diagnosis and intervention. To rebalance this situation we devised the first clinical assessment of reading in Serbian, the Serbian Word Reading Test (SWRT) (Vukovi ́c, 2015).

This paper describes the test and reports on its initial psychometric properties. It goes on to examine the reading performance of a cohort of Serbian speakers with aphasia after stroke, with a view to ascertaining patterns of breakdown in Serbian. The main objective was to determine whether the SWRT achieved acceptable levels of psychometric quality when applied with people with aphasia and whether it was successful at highlighting potential expected differences in patterns of breakdown across aphasia subtypes and word classes.

2. Method

2.1. Participants

Two groups took part in the study: 51 individuals with aphasia due to cerebrovascular accident (CVA) and 50 neurologically healthy individuals. Inclusion criteria for the people with aphasia were: age >21 years; no previous history of language disorder; previously literate, with no report of pre-morbid reading difficulties; aphasia caused by CVA in the left hemisphere; at least three months since their stroke; able to understand the examiner's instructions (rated as 2 or more on the Serbian adaptation of the BDAE Aphasia Weighting Scale); no floor effect (zero score) on the word reading tasks of the Serbian BDAE and the Serbian Aphasia Screening Test (Vuković, 2010, 2015); preserved natural or corrected vision, determined by ophthalmologic examination. People with dysarthria and apraxia of speech were excluded based on oral motor assessments and apraxia batteries (Dabul, 2000; Wertz, LaPointe, & Rosenbek, 1984).

All individuals were monolingual native speakers of Serbian. Participants in the aphasia group had received speech-language therapy support in the acute phase whilst they were inpatients, but no one had received any therapy since discharge. Testing for the aphasia group took place in a hospital outpatient Rehabilitation Clinic. The same in/exclusion criteria, apart from stroke and aphasia variables, were applied to the control participants. People in the control group were assessed in clinic or at home. All recruits were volunteers and received no reward in payment or kind.

Table 1
Age summary for the aphasic subgroups.

Aphasia types	N	Age			
		Min	Max	Mean	SD
Broca's	14	35	69	54.43	8.27
Wernicke's	7	47	69	58.71	9.48
Conduction	6	62	70	65.33	3.07
Anomic	5	47	70	59.00	9.46
Transcortical Motor	7	53	70	61.00	6.24
Transcortical Sensory	6	43	69	53.99	9.39
Subcortical Motor	7	47	69	57.33	8.54
Total Aphasia Group	51	35	70	58.57	8.30

Table 2
Distribution of participants according to aphasic subgroups and severity of aphasia based on the Serbian BDAE total raw scores.

Aphasia types	N	Min	Max	Mean	SD
Broca's	14	205	385	277.00	61.68
Wernicke's	7	135	257	184.29	43.01
Conduction	6	224	330	274.50	35.27
Transcortical motor	7	271	436	347.14	48.99
Transcortical sensory	6	172	297	215.50	45.13
Subcortical motor	7	352	409	383.00	22.10
Anomic	6	396	470	442.60	28.15

Table 3
Distribution of participants according to aphasic subgroups and severity of aphasia based on the Serbian BDAE rating scale.

Type of aphasia	N	%	Severe aphasia	Moderate aphasia	Mild aphasia
Broca's	14	27.45	5	6	3
Wernicke's	7	13.73	4	3	0
Conduction	6	11.76	2	4	0
Anomic	5	9.80	0	0	5
Transcortical Motor	7	13.73	1	4	2
Transcortical Sensory	6	11.76	3	2	1
Subcortical Motor	6	11.76	0	2	4
Total	51	100	15	21	15

There were no statistically significant differences between the group with aphasia and the control group either by gender (Aphasia group female 22 (42%), Male 29; Control group Female 27 (54%), male 23; $\chi 2 = 1.44$, df = 1, rC = 0.12, p = .23), age (Aphasia group mean 58.57 years, SD 8.30; Control group mean 60.14, SD 8.60; T = 0.93, df = 99, p = .35), or years of education (Aphasia group mean 13.06 years, SD 1.96; Control group mean 12.92, SD 11.89; T = 0.36, df = 99, p = .71). All patients were right-handed. Age summary for the aphasic subgroups appears in Table 1.

Recruitment to the study and all testing was conducted in accordance with the ethical standards specified in the Helsinki Decla- ration, and the protocol was approved by the local human research ethics committee.

Assignment to aphasia subtypes followed the categories of the BDAE and Helm-Estabrooks & Albert (Helm-Estabrooks & Albert, 2004). Accordingly, in addition to the BDAE labelled cortical aphasias the present cohort included individuals with anterior capsu- lar/putaminal aphasia, labelled below as Subcortical Motor aphasia. Overall aphasia severity was derived from the Serbian BDAE overall scores and BDAE Severity Rating Scale (Tables 2 and 3). Recruits fell between ratings 2–4. Two (here taken as 'severe' aphasia) represents: Conversation about familiar subjects is possible with the help of the listener. There are frequent misunderstandings in communication, but the patient actively participates in it. Three (moderate): The patient can discuss everyday topics with little or no help. However, reduction of speech and/or comprehension makes conversation about certain material difficult or impossible. Four (mild): Some obvious loss of fluency of speech or comprehension, without noticeable limitations on ideas expressed or form of expression.

2.2. The Serbian Word Reading Test (SWRT)

The test consists of six subtests: Reading aloud of 1) concrete nouns, 2) abstract nouns, 3) function words (auxiliaries; conjunctions; prepositions), 4) verbs, 5) adjectives, and 6) plausible non-word nouns (See appendix: Tables A.1, A.2, A.3). These categories were selected based on concreteness/ imageability, grammatical word class and lexicality being consistently shown as variables that can characterise different forms and severities of acquired dyslexia (Silver and Halpern, 1992; Goodglass et al., 1998; Pedersen et al., 2004). Serbian has a transparent orthography; therefore the battery did not include subtests examining effects of regularity. None of the handful of words in Serbian that do show irregular spelling appeared amongst the items. This means that the SWRT (or any other Serbian word reading test) is unable to identify surface dyslexia purely on letter-by-letter sounding out errors. This issue is taken up in the discussion, concerning what means might identify surface dyslexia in transparent orthographies.

Words were selected to reflect a range of frequency of appearance in written Serbian based on total occurrences of the word across 10979 texts of varied styles used as sources (Lukić, 1983). Table 4 provides summary statistics for frequency, with full details in the appendix (Table A.4). No frequency data are available for different verb forms in Serbian. Concrete nouns all named an object, abstract nouns all named a concept (see appendix). The non-word nouns were plausible words in Serbian. Serbian is biscriptal. Three phonemes represented by a complex single letter in the Cyrillic script are represented by digraphs in the Latin script. This led to five words in the Latin script having one extra letter compared to the Cyrillic version. Sound and syllable length were identical across both scripts.

Each category contained 20 words printed on separate cards. For each individual tested Cyrillic or Roman/Latin script versions were selected based on greatest familiarity to the participant. Respondents received a randomly ordered card showing one word at a time. All items in one category were presented sequentially. The examiner recorded responses live and checked them afterwards against an audio-recording. Two measures were derived: reading time for the whole subtest and response accuracy. Accuracy was judged solely on integrity of reading the word aloud, irrespective of whether the person understood the word or could name the letters

Table 4
Summary frequency distribution by word class, based on Lukić, 1983.

Class of words	N	Median	IQR
Concrete nouns	20	430.00	1739
Abstract nouns	20	142.50	370
Adjectives	20	95.00	275
Function words	19[a]	757.00	2067

N = Number of words, IQR = Interquartile Range.
[a] No data was available for one auxiliary verb (see Appendix A4).

or spell the item. For each correct word the respondent received 1 point, giving a maximum per subtest of 20, and 120 for the whole battery.

Serbian is a highly inflected Slavic language where nouns and verbs cannot occur without an affix marking case, number, gender and so forth. In the test nouns and adjectives were delivered as nominative singular forms and verbs in their infinitive form, or for some irregular verbs the 3rd person singular (appendix 1).

Reading errors were classed into six categories: articulatory, phonological, morphological, semantic, neologistic and visual (Vuković et al., 2016; Vuković, 2015), reflecting variables commonly employed to describe and classify aphasic and dyslexic impairment (Kay et al., 1992;

LaPointe et al., 1998; Hillis & Caramazza, 1992). Articulatory changes included slowed or effortful speech with phonetic distortions but correctly discernible target word. Phonological errors represented instances of perceived phoneme substitution, addition, omission or transposition – for example: <глава>/glava/(head) is heard as <клава>/klava/; <храброст>/hrabrost/(courage) is heard as <'праброст>/prabrost/; <поспан>/pospan/(sleepy) is heard as <попасан>/popasan/. Morphological errors indicated responses in which there is addition and/or replacement of bound morphemes. For example, the verb "veruje", (believes; third person singular) is produced as "verujete" (you believe, second person plural), or maˇstati (infinitive, to imagine) becomes maˇstaju (third person plural), or even a totally different word class, e.g. maˇstovit (adjective; imaginative). Semantic errors covered responses where the target was read as another word with a related meaning, e.g., човек/ˇcovek (man) is read as ˇzena (woman), доктор (doctor) as lekar (physician). Neologistic errors were noted when a word was read as a non-word, for example, путер,/puter/ (butter) is produced as "mulad" (nonword in Serbian), бицикл, bicikl/bitsikl/, (bicycle) as "boktol" (nonword). Visual errors referred to responses that where orthographically similar to the target written word – e.g. instead of "mudro" (wise) the person read "mutno" (muddy/murky).

A second scorer, blind to the first rater's classifications, rated all responses for the presence or not of an error, and if an error was present for the type of error occurring. The first scorer re-rated all responses blind to the original classifications. Intraclass correlations for inter- and intra-rater agreement on the presence or not of errors and the class of error present were all highly significant ($r = 0.99$; $p < .001$).

2.3. Statistical data processing

Results were summarised applying descriptive statistics to number of items correctly read. To examine the psychometric properties of the SWRT internal consistency was measured using Kuder-Richardson 20. Cut-off scores were established from the performance of the neurologically healthy group employing Receiver Operating Characteristics. Comparison between variables (with versus without aphasia; subgroups with aphasia; different word classes) was based on chi-square test, T-tests, Kruskal-Wallis H-test, Mann-Whitney *U* test and multiple correlation analysis according to level of data and normality of distribution determined via Kolmogorov Smirnov testing. Specific procedures are detailed in the results.

3. Results

Table 5 provides descriptive statistics for responses obtained on the SWRT for the control group and group with aphasia overall. Table 6 summarises completion times for the subtests. Only one error

Table 5
Comparison of scores on the SWRT between the people with aphasia and the control group.

Word type	Groups	N	Min	Max	Mean	SD	SEm	t (df 99)	p
Concrete nouns	Aphasia	51	8	20	16.10	3.60	0.50	−7.76	<.001
	Control	50	20	20	20.00	0.00	0.00		
Abstract nouns	Aphasia	51	5	20	13.80	4.81	0.67	−9.09	<.001
	Control	50	20	20	20.00	0.00	0.00		
Verbs	Aphasia	51	1	20	13.06	4.31	0.60	−11.34	<.001
	Control	50	19	20	19.98	0.14	0.02		
Adjectives	Aphasia	51	3	20	12.92	4.90	0.70	−10.20	<.001
	Control	50	20	20	20.00	0.00	0.00		
Function words	Aphasia	51	5	20	15.14	4.18	0.58	−8.22	<.001
	Control	50	20	20	20.00	0.00	0.00		
Non-words	Aphasia	51	0	19	5.22	5.44	0.76	−18.95	<.001
	Control	50	17	20	19.88	0.48	0.06		

Notes: SEm = standard error of the mean.

was recorded amongst the control speakers. Across all people with aphasia total errors was 1981 (median 43, IQR 20–55).

According to both achievement measures respondents with aphasia showed significantly lower scores for the total score as well as on individual subtests and differed significantly in reading speed. These results demonstrate strong criterion validity of the SWRT.

Results of Kuder-Richardson 20 analysis show that the SWRT is a reliable measuring instrument. Good test reliability was recorded at the scale level as a whole (KR-20 = 0.98). At the level of the individual subscales, reliability was also high, with the following coefficients: concrete nouns, KR20 = 0.90; abstract nouns KR20 = 0.94; functional words KR20 = 0.89; verbs KR20 = 0.93; adjectives KR20 = 0.95; and non-words KR20 = 0.98.

To examine the discriminatory power of the test we conducted a ROC (Receiver Operating Characteristics) analysis. Results dis- closed that SWRT has strong classificatory power for separating persons with and without impaired reading ability. Based on the size of the area under the curve (area = 0.998; standard error 0.002; 95% confidence interval, 0.995–1.00; p <.001), people with aphasia were 99% more likely to score less on the SWRT than people in the control group.

The optimal boundary score for separating people with aphasia from control participants was 118. This gave a specificity of 0.96, sensitivity 0.98: i.e., with a cut-off of 118 (from maximum 120), the SWRT gives 98% correct positive results, and 96% correct negative results. Based on this favourable outcome we proceeded to examine performance for the aphasia group in relation to subtest scores. We examined the relationship of performance on the Serbian adaptation of the BDAE (Goodglass and Kaplan, 1972) with the subtest scores of the SWRT. Table 7 illustrates the results in relation to the BDAE receptive reading tasks; Table 8 gives the results in relation to the BDAE oral expressive reading subtests. The highest correlations are at a good level in both comparisons, though the correlations between SWRT and e.g. symbol and word matching and word picture matching (Table 7), while still statistically significant, are more moderate.

Table 7 shows strong correlations between oral reading of concrete nouns and comprehension of oral spelling, oral reading of

abstract nouns and reading sentences and paragraphs, and oral reading of adjectives and reading sentences and paragraphs; the remaining correlations were moderate. Table 8 shows all correlations were strong between SWRT subtests and BDAE reading tests, except for the correlation between

Table 6
Comparison of subtest total reading time (seconds) on SWRT between respondents with aphasia and the control group.

Word type	Groups	N	Min	Max	Mean	SD	SEm	t (df 99)	p
Concrete nouns	Aphasia	51	17	95	43.90	18.45	2.58	11.18	<.001
	Control	50	8	30	13.76	4.81	0.68		
Abstract nouns	Aphasia	51	17	120	53.76	23.33	3.26	11.34	<.001
	Control	50	8	37	15.16	5.87	0.83		
Verbs	Aphasia	51	16	150	59.08	27.06	3.78	11.03	<.001
	Control	50	9	36	16.04	5.41	0.76		
Adjectives	Aphasia	51	16	210	59.51	32.63	4.57	9.34	<.001
	Control	50	8	38	15.52	5.70	0.80		
Function words	Aphasia	51	16	90	45.51	19.96	2.79	11.12	<.001
	Control	50	7	28	13.34	4.40	0.62		
Non-words	Aphasia	51	40	182	93.80	45.47	6.36	10.81	<.001
	Control	50	12	47	23.28	7.71	1.09		

Table 7
Spearman's correlations between SWRT word reading scores and reading comprehension subtests from the Serbian BDAE.

BDAE Subtests	SWRT Subtests					
	Concrete nouns	Abstract nouns	Verbs	Adjectives	Func tion words	Non-words
Symbol and word discrimination	.45**	.56***	.40**	.48**	.53***	.50***
Word recognition	.51***	.55***	.50***	.51***	.52***	.48***
Comprehension of oral spelling	.70***	.58***	.52***	.67***	.63***	.46**
Word picture matching	.48***	.49***	.41**	.52***	.44**	.37**
Reading sentences and paragraphs	.65***	.71***	.64***	.72***	.66***	.73***

$p < .01$**; $p < .001$***

Table 8
Spearman's correlation between SWRT word reading scores and oral reading subtest from the Serbian BDAE.

BDAE Subtests	SWRT Subtests					
	Concrete nouns	Abstract nouns	Verbs	Adjec tives	Function words	Non-words
Oral reading of words	.60***	.63***	.50***	.61***	.62***	.61***
Oral sentence reading	.70***	.71***	.62***	.68***	.68***	.69***

$p < .001$***

oral reading of verbs and oral reading of words.

As regards the relationship between overall BDAE severity grading and performance across subtests Table 9 illustrates the

Table 9
Mean (SD) score on SWRT according to severity of aphasia.

SWRT subtest	Severe aphasia (n = 15)	Moderate aphasia (n = 21)	Mild form of aphasia (n = 15)
	Mean (SD)		
Concrete nouns	13.93 (2.73)	15.57 (3.98)	19.00 (1.30)
Abstract nouns	10.87 (4.25)	13.05 (4.53)	17.80 (2.85)
Verbs	10.67 (3.26)	11.95 (4.14)	17.00 (2.56)
Adjectives	9.20 (4.09)	12.43 (4.41)	17.33 (2.28)
Functional words	12.53 (3.77)	14.62 (4.23)	18.47 (1.72)
Non-words	1.07 (1.2 8)	4.76 (4.54)	10.00 (5.61)
Total score	58.33 (16.58)	71.95 (23.04)	99.47 (13.88)

Table 10
Descriptive outcomes for completion time (seconds) for reading on SWRT subtests according to severity of aphasia.

SWRT subtest	Severe aphasia (n = 15)	Moderate aphasia (n = 21)	Mild aphasia (n = 15)
	Mean (SD)		
Concrete nouns	52.40 (20.62)	48.86 (20.41)	32.86 (12.75)
Abstract nouns	60.60 (20.51)	58.33 (25.92)	40.53 (17.18)
Verbs	69.27 (23.72)	68.24 (31.41)	45.40 (22.57)
Adjectives	69.53 (19.64)	68.95 (42.35)	44.73 (22.95)
Functional words	51.67 (19.49)	47.81 (20.89)	36.13 (16.66)
Non-words	90.60 (36.39)	102.14 (54.46)	85.33 (40.39)
Total score	400.53 (115.00)	393.58 (178.75)	285.00 (122.15)

gradation of mean (SD) scores across severity bands. People with severe aphasia had a statistically significantly lower score than those with moderate aphasia in reading non-words ($U = 73.50$, $p = .006$).

People with severe aphasia, had a statistically significantly lower score than those with mild form of aphasia, in total score ($U = 6.00$, $p < .001$), concrete nouns ($U = 9.50$, $p < .001$), abstract nouns ($U = 20.50$, $p < .001$), verbs ($U = 13.50$, $p < .001$), adjectives ($U = 7.00$, $p < .001$), function words ($U = 14.50$, $p < .001$), and non-words ($U = 7.50$, $p < .001$).

People with moderate aphasia had a statistically significantly lower score than those with mild form of aphasia, in total score ($U = 52.50$, $p = .001$), concrete nouns ($U = 67.50$, $p = .003$), abstract nouns ($U = 58.50$, $p = .001$), verbs ($U = 46.00$, $p < .001$), adjectives ($U = 57.00$, $p = .001$), function words ($U = 76.00$, $p = .008$), and non-words ($U = 75.00$, $p = .008$).

A similar pattern emerged in relation to time taken to complete subtests (Table 10). Subjects with severe aphasia, had a statistically significantly slower completion time than those with mild forms of aphasia, in concrete nouns ($U = 37.00$, $p = .002$), abstract nouns ($U = 52.00$, $p = .01$), verbs ($U = 54.50$, $p = .01$), adjectives ($U = 47.50$, $p = .007$), and functional words ($U = 63.50$, $p = .04$). Individuals with moderate aphasia, had a statistically significantly slower completion speed than those with mild form of aphasia, in concrete nouns ($U = 78.50$, $p = .008$), abstract nouns ($U = 87.50$, $p = .02$), verbs ($U = 93.50$, $p = .04$), and adjectives ($U = 90.50$, $p = .03$).

3.1. Performance across word categories

For people with aphasia overall (see Tables 2–3 for aphasia subtypes), based on mean scores, concrete nouns proved most suc- cessful, followed by function words, then abstract nouns, adjectives and verbs, with non-words by far least successful (Table 5). Mean time taken to complete subtests reflected this (Table 6), with an overall order of concrete nouns quickest, followed by function words, abstract nouns, verbs and adjectives, and non-words significantly slowest. Subtest comparisons (Table 11) indicated people with aphasia were statistically more successful reading concrete nouns compared to abstract nouns, verbs, adjectives, functional words and non-words. Table 12 provides outcomes for the same comparisons based on time to complete the subtest. A possible confounding factor with word class concerns word frequency. Word classes differed in mean/median frequency *of occurrence in the text corpus* (Table 4); *see Methods)*, although one way

Table 11
T test comparisons between subtests for individuals with aphasia showing t value and p level.

Subtests	Abstract nouns	Verbs	Adjectives	Function words	Non-words
Concrete nouns	6.18***	7.60***	8.14***	2.91**	16.72***
Abstract nouns		2.14*	2.27*	3.63**	14.23***
Verbs			NS	6.17***	14.74***
Adjectives				5.93***	13.05***
Function words					16.45***

Notes: ***p <.001, **p <.01, *p < 0.05. NS - statistically nonsignificant.
All df values are equal 49.

ANOVA with post hoc corrected comparisons showed no statistically significant differences in frequency ratings between word groups (F = 2.363, df1 = 3, df = 75, p = .078, $n^2 = 0.08$). We found a strong correlation between how many people with aphasia correctly read a word and word frequency for concrete and abstract nouns, adjectives and function words combined (n 79; Spearman's rho, two tailed, r = 0.522, p <.001). The point is taken up in the discussion.

We inspected for possible associations of demographic variables with test scores. Outcomes showed no statistically significant correlations between gender and achievement on the SWRT, nor for years of education. There was an association of scores with age, albeit a weak one. The relationship of age to subtest scores was statistically significant for verbs (r = − .33, p = .01), adjectives (r = − 0.29, p = .03), functional words (r = -. 28, p = .04), and non-words (r = − 28, p = .04).

As regards possible relationships between subtests and the total test score, as well as between individual subtests, strong in- tercorrelations emerged (Table 13).

Further investigation examined for possible differences between aphasic subgroups. Outcomes for their SWRT scores are displayed in Table 14. Tables 2–3 give the relative size of the subgroups as well as their relative severity based on BDAE scores and ratings. Based on overall raw scores for

BDAE one-factor analysis of variance showed significant differences between aphasia groups (F = 23.07, df1 = 6, df = 44, p = .001, η2 = 0.75).

Post hoc testing (Scheffe test) show that people with Broca's aphasia (M = 277.00, SD = 61.68) differed from those with Wer- nicke's, (M = 184.29, SD = 43.01), anomic (M = 442.60, SD = 28.15) and subcortical motor aphasia (M = 383.00, SD = 22.10). Individuals with Wernicke's aphasia (M = 184.29, SD = 43.01) differed significantly from those with anomic (M = 442.60, SD = 28.15), transcortical motor (M = 347.14, SD = 48.99) and subcortical motor aphasia (M = 383.00, SD = 22.10). Participants with conduction aphasia (M = 274.50, SD = 35.27) differed significantly from those with anomic (M = 442.60, SD = 28.15), and subcortical motor aphasia (M = 383.00, SD = 22.10).

As regards different word classes concrete words proved easiest across all aphasia subgroups, with function words consistently second and non-words uniformly last. The rank order correlation of which aphasia subgroups performed best-worst across the different word classes was highly significant (Cronbach 0.980, p <.001), with the anomia and subcortical motor aphasia consistently achieving the two highest rankings and Wernicke's and conduction groups generally the two lowest rankings.

Kruskal-Wallis H tests showed statistically significant between group differences with respect to scores in reading concrete nouns (H = 16.73, df = 6, p = .010). The group with Wernicke's aphasia scored lowest on mean scores (conduction on median), significantly poorer than people in the groups with Broca's (Mann-Whitney U = 25.00, p = .033), transcortical sensory aphasia (U = 14.00, p = .016), subcortical motor (U = 1.50, p = .003) and anomic aphasias (U = 0.50, p = .004). The group with transcortical motor aphasia performed just significantly lower than those with subcortical motor (U = 7.00, p = .038) and anomic aphasia (U = 5.50, p = .045), the latter two representing the highest scorers. The group with conduction aphasia also achieved significantly poorer scores than those with anomia (U = 1.00, p = .024) and subcortical motor aphasia (U = 1.00, p = .017).

Regarding abstract nouns (*H* = 20.75, df = 6, *p* = .002), all groups performed significantly lower than the anomic and subcortical aphasia groups. These two did not score significantly differently to each other. The Wernicke's aphasia group also scored significantly poorer than the groups with Broca's (*U* = 24.00, *p* = .028), conduction (*U* = 3.50, *p* = .031), subcortical motor (*U* = 0.00, *p* = .002), and anomic aphasia (*U* = 0.00, *p* = .003). The Broca's aphasia group also scored significantly poorer than the groups with anomic (*U* = 7.00, *p* = .009), and subcortical motor aphasia (*U* = 9.50, *p* = .007). The group with conduction aphasia scored significantly poorer than the groups with anomic

($U = 2.00$, $p = .041$), and subcortical motor aphasia ($U = 0.00$, $p = .010$). The group with transcortical motor aphasia scored significantly poorer than the group with anomic aphasia ($U = 4.00$, $p = .025$).

For verb reading ($H = 22.41$, df = 6, $p = .001$) the groups with subcortical motor and anomic aphasia performed highest, with significant differences between them and all other groups. They did not score significantly differently from each other. All other between group comparisons were statistically insignificant.

The group with anomic aphasia had a higher score than groups with Broca's ($U = 8.00$, $p = .012$), Wernicke's ($U = 0.50$, $p = .004$), conduction ($U = 0.00$, $p = .014$), transcortical motor ($U = 1.50$, $p = .008$), and transcortical sensory aphasia ($U = 1.50$, $p = .013$). The group with subcortical motor aphasia representing a higher score with significant differences than the groups with Broca's ($U = 8.00$, $p = .005$), Wernicke's ($U = 0.00$, $p = .002$), conduction ($U = 0.00$, $p = .010$), transcortical motor ($U = 0.00$, $p = .002$), and transcortical sensory aphasia ($U = 1.00$, $p = .006$).

Outcomes for reading adjectives (H = 21.96, df = 6, p = .001) also revealed significant differences between groups, with the anomic and subcortical aphasia groups different to all other groups (though not between each other). Follow-up comparisons showed significant differences between individuals with subcortical motor aphasia and Broca's (U = 10.00, p = .008), Wernicke's (U = 0.00, p = .002), conduction (U = 0.00, p = .009), transcortical sensory aphasia (U = 1.50, p = .013), and

Table 12
T Test comparison of completion time across word category subtests for individuals with aphasia.

Subtests	Abstract nouns	Verbs	Adjectives	Function words	Non-words
Concrete nouns	6.90***	6.71***	5.72***	NS	9.84***
Abstract nouns		3.12**	2.69**	6.12***	8.46***
Verbs			NS	6.41***	7.80***
Adjectives				5.10***	7.47***
Functional words					9.68***

Notes: showing t value (all df values 49) and p value.
***p <.001, **p <.01, *p < 0.05. NS statistically nonsignificant.

transcortical motor aphasia (U = 0.50, p = .005). The group with anomic aphasia had a higher score than groups with Wernicke's (U = 1.00, p = .005), conduction (U = 2.00, p = .046) and transcortical motor aphasia (U = 5.00, p = .041). In addition, the groups with Wernicke's aphasia scored significantly differently to the group with Broca's aphasia (U = 22.50, p = .021).

As regards function words reading, again significant differences emerged (H = 17.35, df = 6, p = .008) across the groups. Comparing subgroups there were significant differences between people with Broca's and Wernicke's aphasia (U = 24.50, p = .030). The group with anomic aphasia had a higher score than groups with Broca’s (U = 10.00, p = .019), Wernicke’s (U = 0.00, p = .003), and transcortical motor aphasia (U = 5.00, p = .037). The group with subcortical motor aphasia, also with higher scores, showed

significant differences to the groups with Broca’s (U = 12.00, p = .012), Wernicke’s (U = 0.00, p = .002), and transcortical motor aphasia (U = 3.50, p = .011).

Finally, non-word reading subgroups again differed significantly (H = 19.77, df = 6, p = .003). In particular there was a significant difference between people with Broca’s and Wernicke’s aphasia (U = 27.00, p = .042). The groups with anomic and subcortical motor aphasia were again the most successful. There was significant differences between individuals with anomic aphasia and Broca’s aphasia (U = 10.00, p = .020), Wernicke’s (U = 1.50, p = .005), conduction (U = 0.00, p = .013), transcortical motor aphasia (U = 1.00, p = .007), and transcortical sensory aphasia (U = 4.00, p = .044). At the same time, there was a difference between group with subcortical motor aphasia and Broca’s (U = 18.00, p = .047), Wernicke’s (U = 3.50, p = .007), conduction (U = 0.00, p = .010), and subjects with transcortical motor aphasia (U = 3.50, p = .012).

With respect to reading times, findings suggest that those with anomic and subcortical motor aphasia consistently required least time to read all word classes (Table 15). On non-word reading people with transcortical motor aphasia also completed the subtest in times comparable to these two groups. However, despite large differences between some means and medians, wide standard deviations and interquartile ranges showed there was considerable intra-group variability, resulting in no statistically significant differences between subgroups in speed of reading concrete nouns (H = 11.30, df = 6, p = .80), abstract nouns (H = 6.99, df = 6, p = .32), verbs (H = 4.42, df = 6, p = .62), adjectives (H = 6.89, df = 6, p = .33), functional words (H = 12.41, df = 6, p = .053), and non-words (H = 8.21, df = 6, p = .22).

3.2. Error types

Table 16 depicts descriptive summaries for the types of reading error according to aphasia subtypes.

With respect to articulation errors people with Broca’s aphasia made significantly more articulation errors than all other groups, including those with subcortical motor aphasia (U 12.50, p = .015), the

Table 13
Spearman's multiple correlation analysis between subtest scores on SWRT for participants with aphasia.

Subtests	Concrete nouns	Abstract nouns	Verbs	Adjectives	Function words	Non-words
Abstract nouns	.84***					
Verbs	.75***	.84***				
Adjectives	.84***	.86***	.85***			
Functional words	.80***	.85***	.84***	.86***		
Non-words	.56***	.66***	.73***	.67***	.64***	
Overall score	.87***	.93***	.92***	.94***	.92***	.80***

Notes: ***$p < .001$.

Table 14
SWRT scores summary across subgroups by aphasia type.

Types of words	Types of aphasia	Min	Max	Mean	SD	Med	IQR
Concrete nouns	Broca's aphasia	9	20	16.29	3.40	17.00	5
	Wernicke's	9	17	13.13	2.94	15.00	5
	Conduction	13	18	15.40	2.51	14.00	4
	Transcort. motor	8	19	15.29	4.53	18.00	7
	Transcort. sensory	10	20	15.50	1.66	17.00	8
	Subcort. motor	16	20	19.00	1.54	19.50	2
	Anomic	17	20	19.20	1.30	20.00	2
Abstract nouns	Broca's aphasia	5	20	12.50	4.27	12.00	6
	Wernicke's	6	11	9.13	1.88	9.00	3
	Conduction	10	16	13.40	2.40	14.00	5
	Transcort. motor	5	19	13.29	5.96	14.00	11
	Transcort. sensory	8	20	15.33	5.35	18.00	11
	Subcort. motor	16	20	18.50	1.76	19.00	3
	Anomic	13	20	18.60	3.13	20.00	4
Verbs	Broca's aphasia	5	19	12.29	3.98	12.00	5
	Wernicke's	6	15	11.00	2.72	11.50	4
	Conduction	8	17	11.40	3.64	10.00	7
	Transcort. motor	1	15	11.00	5.19	13.00	7
	Transcort. sensory	8	16	12.33	3.50	13.50	7
	Subcort. motor	16	20	18.17	1.83	18.50	4
	Anomic	15	20	17.18	2.16	19.50	4
Adjectives	Broca's aphasia	3	20	12.86	4.89	13.00	7
	Wernicke's	3	14	8.50	3.74	9.50	6
	Conduction	8	16	10.40	3.57	8.00	6
	Transcort. motor	4	17	11.43	4.65	13.00	8
	Transcort. sensory	8	17	13.50	3.93	15.50	8
	Subcort. motor	17	20	18.83	1.16	19.00	2
	Anomic	13	20	17.00	2.91	18.00	6
Function words	Broca's aphasia	5	20	14.86	4.34	16.00	5
	Wernicke's	11	15	12.00	1.41	11.50	2
	Conduction	9	20	13.40	4.93	12.00	10
	Transcort. motor	8	17	14.14	4.56	17.00	8
	Transcort. sensory	9	20	15.33	4.54	16.00	10
	Subcort. motor	17	20	19.17	1.16	19.50	2
	Anomic	17	20	19.00	1.41	20.00	3
Non-words	Broca's aphasia	0	17	4.86	5.02	4.00	7
	Wernicke's	0	10	1.63	3.46	0.00	2
	Conduction	1	8	3.00	2.82	2.00	4
	Transcort. motor	0	9	2.57	3.10	17.00	8
	Transcort. sensory	0	11	4.50	4.32	16.00	10
	Subcort. motor	4	17	10.00	5.40	19.50	2
	Anomic	5	19	13.00	5.52	20.00	3

Notes: Med. Median; IQR Interquartile range; Transc = transcortical; Subcort. = subcortical.

only other group to make more than a negligible number of such errors. The point is taken up in the discussion section.

Phonological errors arose only in the groups with Broca's, Wernicke's, conduction and transcortical motor aphasias. Individuals with conduction aphasia attained significantly more errors than people in the other groups. The remaining groups who evidenced phonological slips did not differ statistically significantly from one another.

Morphological errors occurred in all types of aphasia except anomic. Errors were most prevalent amongst people with Broca’s aphasia and transcortical motor aphasia, between whom there was not a significant difference. However, they both differed signifi- cantly from all other groups in susceptibility to morphological derailments. The group with Wernicke’s aphasia produced significantly fewer morphological errors than the conduction aphasia group (p <.01).

Semantic errors were found in all types of aphasia, except subcortical motor aphasia (and negligible totals in transcortical motor and Broca’s. aphasia). Misreadings appeared most often in people with

Table 15
Descriptive outcomes for completion time (seconds) for reading on SWRT subtests according to aphasia subtype.

Word class	Aphasia type	Min	Max	Mean	SD	Med	IQR
Concrete nouns	Broca’s	25	95	48.43	20.45	46.00	17
	Wernicke’s	32	61	45.63	11.19	40.50	20
	Conduction	25	104	59.40	32.79	69.00	60
	Transcort. motor	37	65	44.29	10.54	39.00	15
	Transcort. sensory	24	51	42.00	10.06	45.00	15
	Subcort. motor	20	37	27.83	5.98	28.50	10
	Anomic	17	64	34.00	19.22	25.00	34
Abstract nouns	Broca’s	28	120	60.43	26.31	53.50	29
	Wernicke’s	42	80	58.25	15.71	58.00	29
	Conduction	30	127	67.80	39.74	75.00	70
	Transcort. motor	39	77	50.29	13.91	45.00	20
	Transcort. sensory	26	72	51.33	16.80	53.50	27
	Subcort. motor	19	52	36.83	12.84	40.00	23
	Anomic	17	80	42.00	24.93	32.00	44
Verbs	Broca’s	30	150	63.29	28.83	62.00	30
	Wernicke’s	44	72	56.38	12.66	53.00	25
	Conduction	50	138	79.80	35.52	79.00	58
	Transcort. motor	42	102	55.14	21.41	48.00	16
	Transcort. sensory	27	105	65.67	31.91	65.00	57
	Subcort. motor	19	80	45.50	24.63	43.50	45
	Anomic	16	91	44.80	30.85	31.00	56
Adjectives	Broca’s	28	210	67.14	44.64	58.00	36
	Wernicke’s	43	75	60.00	15.35	60.50	30
	Conduction	35	141	77.00	42.40	80.00	76
	Transcort. motor	40	97	54.43	19.99	45.00	17
	Transcort. sensory	32	100	65.17	28.52	64.00	52
	Subcort. motor	16	58	36.67	15.74	35.50	29
	Anomic	17	93	47.60	32.49	33.00	61
Functional words	Broca’s	24	90	51.29	19.88	50.00	33
	Wernicke’s	26	75	46.25	14.36	45.00	14
	Conduction	30	100	67.60	31.40	85.00	59
	Transcort. motor	36	62	42.57	9.32	39.00	10
	Transcort. sensory	24	70	45.00	15.79	44.00	24
	Subcort. motor	16	45	27.50	10.63	26.50	19
	Anomic	17	60	32.40	17.98	27.00	33
Non-words	Broca’s	41	180	108.71	41.27	109.00	74
	Wernicke’s	73	158	101,28	35.50	82.00	72
	Conduction	65	245	113.20	75.24	95.00	106
	Transcort. motor	51	120	75.43	25.15	69.00	46
	Transcort. sensory	65	182	115.17	49.12	93.00	94
	Subcort. motor	35	120	71.67	31.89	73.00	58
	Anomic	22	95	67.60	33.33	89.00	61

Notes: Med = median; IQR = Interquartile range; Transcort. = transcortical; Subcort. = subcortical.

transcortical sensory, followed by Wernicke’s aphasia. The performance of the group with transcortical sensory aphasia was not significantly different to the group with Wernicke’s aphasia, but both these groups made significantly more semantic errors than each other group.

Apart from two isolated misreading in the conduction aphasia group neologisms were identified almost exclusively in Wernicke’s and transcortical sensory aphasia groups. The differences between

Table 16
Error types on SWRT according to aphasia subtype.

Error types	Aphasia type	Min	Max	Mean	SD	Med	IQR
Articulation	Broca's	4	47	25.00	11.39	27.00	12
	Wernicke's	0	0	0	0	0	0
	Conduction	0	2	0.40	0.89	2.00	2
	Transcort. motor	0	5	2.29	1.70	2.00	3
	Transcort. sensory	0	0	0	0	0	0
	Subcort. motor	3	17	12.17	6.73	16.00	13
	Anomic	0	1	0.60	0.54	1.00	1
Phonological	Broca's	0	9	4.14	3.03	4.50	5
	Wernicke's	1	5	2.50	1.41	2.00	3
	Conduction	23	46	36.00	8.80	39.00	16
	Transcort. motor	2	12	6.00	3.69	6.00	4
	Transcort. sensory	0	0	0	0	0	0
	Subcort. motor	0	0	0	0	0	0
	Anomic	0	0	0	0	0	0
Morphological	Broca's	0	28	14.21	7.92	16.50	11
	Wernicke's	1	4	2.88	0.99	3.00	2
	Conduction	4	6	5.00	0.70	5.00	1
	Transcort. motor	7	31	14.86	8.35	12.00	12
	Transcort. sensory	1	3	2.33	0.81	2.50	1
	Subcort. motor	0	12	3.17	4.40	2.00	4
	Anomic	0	0	0	0	0	0
Semantic	Broca's	0	5	1.64	1.49	2.00	2
	Wernicke's	10	18	15.00	3.20	16.00	6
	Conduction	0	13	6.40	6.02	9.00	12
	Transcort. motor	0	4	1.73	1.00	0.00	3
	Transcort. sensory	12	34	21.67	9.26	22.00	18
	Subcort. motor	0	0	0	0	0	0
	Anomic	0	9	3.83	3.80	5.00	7
Neologisms	Broca's	0	0	0	0	0	0
	Wernicke's	25	48	35.00	7.63	34.00	12
	Conduction	0	2	0.60	0.89	0.00	2
	Transcort. motor	0	0	0	0	0	0
	Transcort. sensory	3	44	17.67	19.03	8.00	38
	Subcort. motor	0	0	0	0	0	0
	Anomic	0	0	0	0	0	0
Visual	Broca's	0	2	0.43	0.64	0.00	1
	Wernicke's	0	2	0.88	0.83	1.00	2
	Conduction	0	1	0.60	0.54	1.00	1
	Transcort. motor	7	15	11.14	3.53	11.00	7
	Transcort. sensory	0	3	1.33	1.50	1.00	3
	Subcort. motor	0	2	1.00	0.63	1.00	1
	Anomic	1	11	6.40	4.09	5.00	8

Notes: 0 = participants did not show this type of error; Transcort. = transcortical; Subcort. = subcortical.

these latter groups were not statistically significant, but they differed significantly from all other groups.

Visual errors appeared amongst all aphasia types, but only significantly so for people in the transcortical motor and anomic groups.

No significant difference arose between these two groups ($U = 6.50$, $p = .072$), but they differed significantly from the other groups.

4. Discussion

Studies of acquired reading disorders in Serbian are scarce (Vuković et al., 2016). One reason is the lack of tests suitable for Serbian speakers. Therefore, the development of this first clinical reading test for speakers of Serbian represents an initial step in removing the barriers to accurate diagnosis and determining the nature of acquired dyslexia in this speaker group. This study aimed to determine whether the SWRT achieved acceptable levels of psychometric quality in distinguishing between people with and without aphasic reading difficulty and whether it succeeded in highlighting potential differences in patterns of breakdown across word classes and aphasia types.

The results demonstrate the test shows high internal consistency and high criterion validity by reliably distinguishing between people with and without aphasia, on total scores as well as subtest outcomes. Moderate to strong correlations between Serbian BDAE reading scores and SWRT outcomes suggest the SWRT has good convergent validity. For the group with aphasia as a whole there were no floor or ceiling effects and distribution of scores suggested the test overall and subtests are sensitive to gradations of severity.

Participants with more severe forms of aphasia performed overall less well than those with mild aphasia, as might be expected. In as far as it was not possible to closely match aphasia subgroups for overall aphasia severity, and numbers were insufficient to reliably control for this in statistical analyses, the issue of severity effects on outcomes and/or the possible interaction of severity and error types remains open from the current work and awaits a study where it is possible to control for severity across subgroups. However, inspection of qualitative findings across subgroups (see below) confirms that, despite severity divergences between subgroups, they showed different trends in performance independent of severity.

Analysis confirmed that word class has a significant effect on reading ability, in keeping with findings from other languages, in particular pointing to concrete words as proving easiest, non-words as most difficult, abstract words poorer than concrete words and verbs lower than nouns (Caramazza & Hillis, 1991; Crisp & Lambon; Plaut & Shallice, 1993; Ralph, 2006). The present study was not constructed as an experimentally controlled investigation to determine the independent effects of word class, image- ability/concreteness, frequency, and lexicality on performance. Even though ANOVA suggested no significant differences between word groups (minus verbs, for which there are no Serbian norms), the role of frequency in contributing to word class differences remains to be decided.

The lack of surface dyslexia type derailments but presence of complex morphological errors also reflects findings from other languages with transparent orthographies and from related languages with intricate morphological marking (Davies, Barbon, & Cuetos, 2013; Dragoy & Bastiaanse, 2010; Hricová & Weekes, 2012; Leheckova, 2001; Ulatowska, Sadowska, & Kadzielawa, 2001).

Few studies have examined function word reading so it remains unclear whether their favoured status in Serbian in this study reflects general trends or relates to some other variable(s) such as frequency, length, morphological status, closed vs open class words, or even processing at different brain sites or within different networks (Boye & Bastiaanse, 2018; Schell, Zaccarella, & Friederici, 2017). Some studies have explained greater difficulty of verbs over nouns as related to greater complexity of verb morphology in English compared to other word classes (Alyahya, Halai, Conroy, & Ralph, 2018; Alyahya, Halai, Conroy, & Ralph, 2018a; Progovac et al., 2018; Rimikis & Buchwald, 2019; Ruigendijk & Friedmann, 2008). That verbs are more susceptible to derailment even when nouns and adjectives possess a complex morphology, as in Serbian, supports arguments for verb difficulty not being restricted solely to morphological status.

The severe impairment of the ability to read non-words is consistent with findings of other studies showing that reading non-words requires more cognitive operations than reading words with meaning, including in neurologically healthy readers (Plaut & McClel- land, 1996). There are likely added calls on attentional, phonological and orthographic-phonological integration processes and possibly phonological-semantic analogy scanning whereby readers search the lexicon for entries resembling the target non-word.

In terms of the qualitative error analyses, variation in which derailments proved more prominent across aphasia subtypes/lesion sites corresponded to predictions from studies outside of Serbian. Thus people with Broca's type aphasia, typically characterised by morphosyntactic breakdown, produced predominantly morphological errors (Progovac et al., 2018; Rimikis & Buchwald, 2019). They also produced proportionately many articulatory errors. This was despite the fact that people with apraxia of speech and dysarthria were excluded from the study, based on motor speech assessments and apraxia screening tests.

There has long been controversy over the delineation of apraxia of speech (Miller & Wambaugh, 2015; Ziegler, Aichert, & Staiger, 2012) and its relationship (or not) to Broca's aphasia (Beveridge & Bak, 2011; Mohr et al., 1978). In the present work, the likely explanation for raised articulatory errors in the group with Broca's aphasia probably relates to differential diagnostic issues with the apraxia tests employed and use of a motor speech examination that relied predominantly on non-verbal tasks and so may have let through people with speech motor impairment. Specifically, the screen employed was an informal, non-validated test from the USA, adapted into Serbian, based on Dabul (2000) and Wertz et al. (1984). It contained only the tasks: diadochokinetic repetitions; oral apraxia test; and repetition of five words of increasing length. All these tasks have been criticised as poorly differential in quantifying speech apraxic behaviour and differentiating apraxic pronunciation errors from dysarthric ones (Miller & Wambaugh, 2015).

People with conduction aphasia made characteristic prominent phonological errors, along with semantic paralexic slips (Kohler, Baretles, Hermann, Ditmann, & Wallesch, 1998; Silver &

Halpern, 1992). Semantic paralexic and neologistic responses marked out Wernicke's aphasia (Goodglass, Wingfield, & Hyde, 1998). The low incidence of visual errors likely reflects that we recruited only people with left hemisphere lesions and with aphasia. This excluded people with right hemisphere and occipital lesions who might be expected to show more visual misreadings in the presence of no or minimal aphasia.

The qualitative error picture is in keeping with anticipated findings given the lesion sites associated with the different aphasic syndromes (Goodglass et al., 1998; Silver et al., 1992). Broca's aphasia links to lesions of the dominant frontal lobe, frontal operculum and insula, which also corresponds to areas related to articulatory and morphosyntactic breakdown. Conduction aphasia is associated with lesions to the arcuate fasciculus and temporal-parietal cortex which are viewed as playing a role in sound perception, phono- logical processing and integration and auditory short term memory (Martin & Ayala, 2004). Lesions of the temporal lobe which are linked to Wernicke's aphasia result in marked phonological and semantic breakdown which would produce extensive phonological and/ or semantic jargon.

As regards the people labelled with anomic aphasia, this aphasic syndrome is typically taken as non-localising, given that difficulty producing words is common to most aphasia types – of course for different reasons across subtypes (Pedersen, Vinter, & Olson 2004; Ralph, Moriarty, & Sage, 2002: Yourganov, Smith, & Fridriksson, 2015). Anomia labels a particular difficulty with word finding and people classed as having anomic aphasia might have been expected to perform poorly on a single word reading task. In fact on some subtests they performed similarly to control speakers. This is likely attributable to the fact that the SWRT does not test comprehension, lexical retrieval or ability to spell words, but merely to read them aloud. As such it may not have challenged people with anomia in their weakest areas and/or the error taxonomy did not transparently capture the circumlocutions and no responses typical of people with anomia. Alternatively, or in addition, it stems from participants with anomia all having mild aphasia (Table 2). Isolated severe anomia is rare, and people with milder anomia may be mainly people with recovered aphasia (Basso, 2003). Detection of performance outside normal limits may be more clear in response time and hesitation metrics than item accuracy. We have noted below the need to conduct more sensitive investigations of response time profiles to further develop SWRT.

With regards to subtest total reading times results showed that aphasic subjects needed most time to read non-words, while least time was spent reading concrete nouns. The control group, although significantly quicker, also took the most time to read non-words, and least for function words. Interpretation of findings for duration is complicated by issues around length and (morphological) complexity, both of which represent significant variables in reading performance (Graves, Desai, Humphries, Seidenberg, & Binder, 2010). Whilst the words across subtests in the SWRT were in general controlled for length, it was not possible to match function words with other classes and morphological status remained a complicating factor in interpreting length measures.

Nevertheless, reading duration has been indicated as an important variable to consider in assessing dyslexia (Webster, Morris, Howard, & Garraffa, 2018). Hence future investigation of the SWRT might benefit from more controlled examination of word length effects that were not possible with the coarse measure of time to complete the whole subtest employed here. Furthermore, for purposes of comparisons of Serbian reading performance with readers across other languages, the factor of sound versus letter based word-length measurement and orthographic parsing would need to be controlled. For instance, in general Serbian lacks di- and trigraph letters (e.g. English, German <sch>). It retains a sequential one letter one sound correspondence, and it has no so-called split digraphs (e.g. the a_e in English hat vs hate).

The SWRT was not designed in itself to differentiate between putative dyslexic syndromes (e.g. surface vs phonological vs neglect dyslexia). However, in as far as it delivers performance contrasts across words of different class and lexicality an error analysis of derailment types has the potential to highlight specific breakdown patterns.

The subdivision of aphasia types in the present study followed procedures (BDAE categories) that have been superseded by other approaches. The diagnostic categories envisaged by the likes of BDAE, WAB (Goodglass & Kaplan, 1972; Kertesz, 1982) and others have been criticised as too English-centric (Beveridge & Bak, 2011; Miller & Lowit, 2014) and for lumping together diverse behaviours within single syndromes that miss important insights and differentiations from finer grained morphological, syntactic and phono- logical analyses (Bates, Wulfeck, & Macwhinney, 1991; Halai, Woollams, & Ralph, 2018; Woollams et al., 2016). Further work with the SWRT might gainfully take an approach that does not commence with a priori groupings or/and that adopts a single case strategy to highlight individual error performance in relation to putative dyslexia types utilizing finer grained and additional analyses of language processes (Henseler et al., 2014). In respect of additional materials, for instance, Serbian is an orthographically transparent language and not typified by surface-dyslexia type errors; detection of these in suprasegmental or other variables would therefore require additional elicitation material (Vuković et al., 2016), examining for instance stress assignment, pseudohomophone lexical judgements, and/or reading of loan words, that in many languages behave differently to the general pattern of phonology and so are exception words (Ferreres, Cuitino, & Olmedo, 2005; Molczanow, Iskra, Dragoy, Wiese, & Domahs, 2019).

5. Conclusion

The aim of this study was to establish the validity and reliability of SWRT for people with aphasia who speak Serbian. Overall, findings indicate that SWRT enables the identification of acquired (single word reading) dyslexia in Serbian speakers, differentiates across levels of severity, and can highlight differences in the profile of error types for individuals and groups, thereby confirming its clinical relevance. Detailed outcomes for comparisons across aphasia subgroups awaits future studies carefully controlling for severity. In addition, SWRT allows characterisation of reading impairment in relation to word class, word frequency and error types, though the relationship of word class and frequency remains to be elucidated in a more experimental setting. This contributes to a closer determination of linguistic deficits/disorders in aphasic syndromes in general, in acquired dyslexia in particular, and, crucially for clinical purposes, at an individual speaker level for purposes of differential diagnosis and treatment planning. We suggested possible additional subtest development necessary to detect the presence of surface dyslexia in Serbian, with its transparent orthography. In terms of the variable of reading rate further work remains to be undertaken to place this on a more objective footing and through this gain greater insights into performance across aphasia subtypes.

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Mile Vukovic: Conceptualization, Methodology, Investigation, Formal analysis, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Tanja Milovanovic:** Investigation, Formal analysis, Resources, Data curation. **Nick Miller:** Formal analysis, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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Appendix A. Serbian Word Reading Test. Subtests and items

Table A.1
Word Reading Test (Serbian, Cyrillic)

Concrete Nouns	Abstract Nouns	Function Words	Verbs	Adjectives	Non-words
ауто	мисао	на	радити	стар	лец
вино	срећа	иза	даје	светао	тис
кућа	страх	поред	пушити	прљав	прил
вода	место	изнад	пливати	сув	клотас
зима	бол	иако	стављати	млад	бозир
крв	храброст	код	кречити	опасан	плед
дечак	љубав	испод	превозити	мокар	талкос
човек	младост	или	прескаче	храбар	сипор
мед	мир	ако	верује	чист	персеп
прозор	лепота	мада	маштати	добар	латасок
хлеб	снага	међутим	испитује	поспан	клећир
путер	изненађење	пре	претражује	плашљив	трулк
доктор	уметност	испред	ловити	мршав	делсип
кревет	слобода	осим	носити	низак	колкат
сунце	мржња	после	пише	веран	зирлец
врата	штета	уместо	мењати	мудар	рил
бицикл	машта	усред	плаче	висок	ледмок
глава	разлог	где	шетати	чврст	чирло
сто	ауторитет	као	пече	марљив	мокас
кључ	чежња	је	стиже	сладак	рнаво

Table A.2
Word Reading Test (Serbian, Latin)

Concrete Nouns	Abstract Nouns	Function Words	Verbs	Adjectives	Non-words
auto	misao	na	raditi	star	lec
vino	sreća	iza	daje	svetao	tis
kuća	strah	pored	pušiti	prljav	pril
voda	mesto	iznad	plivati	suv	klotas
zima	bol	iako	stavljati	mlad	bozir
krv	hrabrost	kod	krečiti	opasan	pled
dečak	ljubav	ispod	prevoziti	mokar	talkos
čovek	mladost	ili	preskače	hrabar	sipor
med	mir	ako	veruje	čist	persep

(*continued on next page*)

Table A.2 (*continued*)

Concrete Nouns	Abstract Nouns	Function Words	Verbs	Adjectives	Non-words
prozor	lepota	mada	maštati	dobar	latasok
hleb	snaga	međutim	ispituje	pospan	klećir
puter	iznenađenje	pre	pretražuje	plašljiv	trulk
doktor	umetnost	ispred	loviti	mršav	delsip
krevet	sloboda	osim	nositi	nizak	kolkat
sunce	mržnja	posle	piše	veran	zirlec
vrata	šteta	umesto	menjati	mudar	ril
bicikl	mašta	usred	plače	visok	ledmok
glava	razlog	gde	šetati	čvrst	čirlo
sto	autoritet	kao	peče	marljiv	mokas
ključ	čežnja	je	stiže	sladak	rnavo

Table A.3
Word Reading Test (English translation)

Concrete Nouns	Abstract Nouns	Function Words	Verbs	Adjectives	Non-words
car	thought	on	work	old	lets
wine	happiness	behind	gives	light	tis
home	fear	by	smoke	dirty	pril
water	place	under	swim	dry	klotas
winter	pain	although	put/place	young	bozir
blood	courage	at	paint	dangerous	pled
boy	love	under	transport	wet	talkos
man	youth	or	jumps over	brave	sipor
honey	peace	if	believes	clean	persep
window	beauty	though	fantasize	good	latasok
bread	strength	however	examines	sleepy	kletchyir
butter	surprise	before	searches	fearful/timid	trulk
doctor	art	in front of	hunt	skinny	delsip
bed	freedom	except	carry	short/small	kolkat
sun	hatred	after	writes	faithful	zirlets
door	damage	instead of	change	wise	ril
bicycle	imagination	amid	cries	tall	ledmok
head	reason	where	walk/stroll	hard/firm	chirlo
table	authority	as	burns	diligent	mokas
key	yearning	is	arrives	sweet/cute	rnavo

Table A.4
Word Frequencies for SWRT

Concrete Nouns	frequency	Abstract Nouns	frequency	Function Words	frequency	Verbs[a]	frequency	Adjectives	frequency	Non-words
auto	73	misao	252	na	24678	raditi	–	star	1114	lec
vino	58	sreća	438	iza	757	daje	–	svetao	71	tis
kuća	7847	strah	520	pored	1347	pušiti	–	prljav	72	pril
voda	1952	mesto	1743	iznad	299	plivati	–	suv	143	klotas
zima	2166	bol	153	iako	287	stavljati	–	mlad	725	bozir
krv	394	hrabrost	87	kod	3479	krečiti	–	opasan	5	pled
dečak	1409	ljubav	265	ispod	532	prevoziti	–	mokar	188	talkos
čovek	4292	mladost	116	ili	774	preskače	–	hrabar	276	sipor
med	76	mir	307	ako	882	veruje	–	čist	314	persep
prozor	1039	lepota	469	mada	112	maštati	–	dobar	1793	latasok
hleb	303	snaga	216	međutim	175	ispituje	–	pospan	16	klećir
puter	10	iznenađenje	82	pre	886	pretražuje	–	plašljiv	45	trulk
doktor	81	umetnost	4	ispred	415	loviti	–	mršav	74	delsip
krevet	466	sloboda	613	osim	115	nositi	–	nizak	24	kolkat
sunce	2651	mržnja	27	posle	3822	piše	–	veran	100	zirlec
vrata	576	šteta	132	umesto	142	menjati	–	mudar	6	ril
bicikl	212	mašta	62	usred	28	plače	–	visok	446	ledmok
glava	1023	razlog	9	gde	2242	šetati	–	čvrst	122	čirlo
Sto	181	autoritet	2	kao	4984	peče	–	marljiv	12	mokas
ključ	33	čežnja	8	je[b]	–	stiže	–	sladak	90	rnavo

[a] Frequency for verbs was taken from the frequency dictionary; however this refers to all verbs forms of a given verb and does not list individual inflections separately.Since the SWRT uses only one (mainly infinitive) form for each verb it is not possible to supply separate frequencies.
[b] Auxiliary verb - no frequency data are available.

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