Research Paper

Reading Assessment for Diagnosing Acquired Reading Disorders in Adults: Theoretical and Practical Aspects of its Development

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Abstract

The study of reading processes is of particular importance in the assessment of cognitive-linguistic functions in both atypical development and acquired disorders of the adult developmental skills system. A comprehensive assessment of cognitive processes allows the selection of the appropriate therapeutic techniques, which in turn contributes to the best possible quality of life following rehabilitation. A common, leading symptom of cognitive dysfunction in adult acquired neurological impairment is a deficit in reading. Our aim was to develop a reading assessment procedure based on national and international theoretical and empirical research to allow for a complex assessment of reading processes. In order to investigate the reliability of the test and to develop an assessment system for it, a large-scale survey was organised. During the analyses, an evaluation system was developed which would allow us to objectively describe not only the fact of impairment but also its extent. Based on our results, the design of the Adult Acquired Reading Assessment and the comprehensive assessment system associated to it have resulted in a complex test procedure that is not only well applicable in clinical diagnostics but also in exploratory empirical work.

Keywords: reading, adults, reading difficulties, reading tests, reading comprehension

Introduction

The appearance of literacy thousands of centuries ago opened up new perspectives in the history of humanity, and this has contributed to the more effective functioning of individuals and society in everyday life to a degree perhaps unprecedented today (Nagy, 2006). The human brain does not fundamentally have distinct networks responsible for reading, however, as a result of evolutionary social demand and the plasticity of the brain, certain pathways have become capable of supporting this now crucial function (Csépe, 2006; Immordino- Yang & Deacon, 2007; Kessler & Treiman, 2015). The digital revolution that started in the second half of the last century, the generalisation of secondary education and the growing popularity of higher education have all contributed to the fact that reading and writing have become an integral part of everyday life (Nagy, 2006).

Nowadays, reading and writing are essential communication tools for all members of society. A wide range of research has emerged in recent decades to provide a deeper understanding of the complex process of reading. Educational, psychological and cognitive neuroscientific advances have continuously shaped the way we have approached cognition, and this has had an impact on the way we think about reading. Although in many cases researchers in different fields of science focus on exploring different aspects of reading, there is a

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unified approach to reading as a complex process rather than an isolated system in the relevant literature. Accordingly, the role of multiple factors in relation to reading is being investigated simultaneously in research (DeDe, 2013a; 2013b; 2013c; Bóna & Steklács, 2020; Józsa & Pap-Szigeti, 2006; Raymer & Rothi, 2018; Tsapkini & Hillis, 2015).

The changing paradigms of reading in the history of science

Several theories have emerged in reading research to describe the mechanisms of reading. The starting point of the initial models was a representation-based conception, in line with the prevailing paradigms in cognitive science at the time, and reading was accordingly studied separately from other processes. This was later replaced by holistic perspectives that sought to define reading in a broader context (Alvermann et al., 2013; Coltheart et al., 2001; Perfetti & Stafura, 2014).

Two major milestones can be observed in the changes of approach that describe the process of reading. The first is the shift from initial traditional theories to cognitive perspectives on reading. Traditional models defined reading as the decoding of written symbols into spoken language, assuming hierarchical interdependent skills in the background, operating as data-driven, bottom-up processes, with the reader himself being a passive participant in the process. Traditional approaches have been replaced by the cognitive orientation, where reading is understood as a concept-driven, top-down process, emphasising the interactive process of reading and the constructivism of text comprehension. These theories introduced schemata as building blocks of the cognitive system and began to explore the role of prior knowledge in reading. The other major shift in approach was the shift from cognitive theories to the metacognitive perspectives that dominate the landscape of reading research nowadays. According to this view, reading is a complex process in which both bottom-up and top-down operations are involved. The metacognitive view is based on the idea that text is processed through the interaction of the reader's different skills, abilities and prior knowledge (Csépe, 2014). Nowadays, sociocognitive theories have emerged to describe reading, in which the role of cognitive processes, sociocultural factors and their interaction are now of particular importance (Alvermann, Unrau & Ruddell, 2013; Coltheart et al, 2001). In other words, to summarise the above mentioned point, it is now much more appropriate to use a framework for a proper understanding of the reading process that includes both data-driven and concept-driven processes, interactions between different knowledge sources, and social and cultural influences on the individual (Perfetti & Stafura, 2014).

Several theoretical frameworks have been developed to describe the operation of developmental and adult reading. Nagy (2004) gives a complex description of the organisation of reading ability, describing the main stages of its development. He defines literacy as a psychological system consisting of routines, skills, knowledge and abilities that build on each other. Their appropriate functioning is of particular importance in complex reading processes such as text processing and comprehension. All these are based primarily on the routines, which are a very fast and automatic system. Nagy (2004) mentions six routines in relation to reading: speech sound recognition, speech sound highlighting, sound word recognition, letter recognition, letter switching and letter recognition. The psychological system organised from the routines is the skill level, of which Nagy (2004) mentions hierarchical complex skills. All of these differ in the number and flexibility of their components, as well as in their operation and the conditions required for their functioning. The next psychological system is knowledge, which involves the person's thought, the conceptual network, i.e. the combined activation of the word routine and its associated concept. The highest psychological system is the ability, which is organised from routines, skills and knowledge. The development of effective literacy skills requires the appropriate functioning of all these systems. Nagy (2006) points out that word reading is a central process of reading ability, as it is the psychological system that stands between letter reading and higher level sentence processing ability. The function of the word reading system is to identify visually recognized words and activate the associated conceptual network. In order to produce appropriate sentence and text comprehension, it is necessary to recognise visually identified words and to ensure the correct functioning of the associated conceptual network. Another, and rather more cognitive, approach to the functioning of reading processes is provided by Perfetti's (1999) framework, who, somewhat in contrast to the above, describes adult reading processes specifically. As before, the importance of the interaction between the different processing operations is also reflected here, as well as the emphasis on word reading and word identification. According to Perfetti (1999), reading takes place through the interaction of three main sources of knowledge: linguistic, orthographic and general cognitive processes. The main mechanisms involved in reading, such as decoding, word identification, meaning retrieval,

sentence and text construction, and inference and control mechanisms, operate on these knowledge sources in both a limited and interactive way. These processes take place within the cognitive system and are linked to both perceptual and long-term memory systems. Reading comprehension is a complex process of first identifying the words and then quickly retrieving the meaning of the words in context. Lexicon is the central element of Perfetti's (1999) framework, situated between word identification and higher level comprehension processes. This is followed by building up of morphemic sequences into syntactic structures, followed by the construction of basic meaning units, followed by the integration of meaning units within and between sentences, and followed by further processes that activate elements of general knowledge necessary for the construction of a general (non-linguistic) representation of the content of the text. Text-level processes include information that goes beyond the literal interpretation of the text, as the reader's prior knowledge of the semantic content and type of the text are revealed, and mechanisms based on prior knowledge and memory are required to allow inferential processes to operate on the basis of the text, and to integrate the information included in the text (Perfetti, 1999; Perfetti & Stafura, 2014; Perfetti & Helder, 2022).

Main aspects of diagnostic assessment of reading

The assessment of reading skills and the identification of atypical development in reading or a dysfunction of the developed reading system are crucial for the child's progress in school or, in adulthood, for the selection of therapeutic techniques and the achievement of an acceptable quality of life.

The identification of specific learning disabilities requires a detailed assessment of the individuals' cognitive abilities profile of the learner, which should be a complex diagnostic process using specific measurement tools developed for this purpose. The integrated results of theoretical knowledge and research in the field of reading provide the basis for an appropriate differential diagnosis of reading disorders (Blomert & Csépe, 2012). Three main dimensions can be identified for the diagnostic assessment of reading: psychological/cognitive, applied/contextual and content/curricular. These have different emphasis at different stages of life. In terms of literacy acquisition, the focus in the initial stage is on the acquisition of appropriate skills and abilities (Csapó et al., 2012). Visual decoding and word reading are two important factors that determine reading. Measuring word-level reading processes is the key when examining cognitive operations of reading. Blomert and Csépe (2012) propose a measurement of reading skills in primary school children. Accordingly, in grade 1, it is essential to investigate letter recognition, decoding, word reading accuracy and fluency, and the reading of words and pseudowords. In the following year, grade 2, it is recommended that the assessment of reading accuracy and fluency should take into account the word frequency and word length factors that influence them. In grade 3, in addition to those recommended in the lower grades, the assessment of letter-sound integration and vocabulary is also recommended. In grade 4, in addition to this, the assessment of sentence and comprehension abilities should be emphasised (Blomert & Csépe, 2012).

In general practice, reading assessment is based on several criteria. Csapó and colleagues (2012) review the key components involved in the diagnostic assessment of reading based on five main reading guidelines. The PISA tests mainly focus on text comprehension processes, including retrieval of information, retrieval of meaning, integration, reflection and evaluation. The PIRLS (Progress in International Reading Literacy Study) assessments focus on the ability to retrieve information explicitly presented in a text, to draw inferences, to interpret, to integrate, and to analyse the form and content of the text. In relation to reading, NAEP (National Assessment of Educational Progress) framework: criteria for students in grades 4, 8 and 12 refers to three main operations: comprehension of the main points of the text, understanding the context and linking it to the reader's prior knowledge, and the analysis of the content and structure of the text. CBAL (Cognitively Based Assessment of, for and as Learning) is a more research-based approach, which involves not only the assessment of reading but also the cognitive skills associated with it. The emphasis is placed on reading comprehension abilities, mental modelling of meaning construction and, the assessment focuses on how the text is applied to the reader's intentions. The Abecedarian Reading Assessment focuses on the assessment of the initial stages of reading acquisition and comprehension skills, and six basic skills are assessed: letter recognition, phonological and phoneme awareness, letter-phoneme correspondence, vocabulary, decoding (Csapó et al., 2012).

Acquired reading disorders in adults

Impairment of any processing involved in or associated with reading can lead to a disturbance in the functioning of reading abilities. The general term for reading disorders in adults, usually as a result of some neurological impairment, is alexia or acquired dyslexia, which refers to an acquired reading disorder and refers to an impairment of the established reading abilities, with some functions being dysfunctional or impaired (Papathanasiou, Coppens & Potagas, 2013; Cherney, 2004; Wollams, 2015). Basically, both hemispheres can be affected by alexia, but the reading disorder associated with language impairment is the result of the damage to the pathway systems of the dominant hemisphere (Cherney, 2004; Denes, Cipolotti & Zorzi, 1998; Wollams, 2015; Coslett, 2012).

In neurological disorders, acquired dyslexia is often investigated in people with aphasia. Aphasia is an acquired cognitive-linguistic disorder with symptoms that predominantly affect the processes that operate language production and processing. Symptoms are manifested across multiple modalities, including reading and writing (Hallowell & Chapey, 2008; Lambon Ralph et al., 2017; Martin & Gupta, 2004; Molnár-Tóth, 2021; Papathanasiou & Coppens, 2013). Persons with aphasia present a varied symptom pattern of impaired reading processes. In aphasics, a relationship has been found between word reading accuracy and performance on reading comprehension tasks, i.e. performance on reading tasks can predict reading comprehension skills (Smith & Ryan, 2020). Symptoms in reading also affect eye movements. Smith and colleagues (2018) found significant differences by task in the number and timing of fixations and saccades in aphasic individuals compared to controls. Among neurological pathologies, cognitive-linguistic processes are frequently investigated in patients diagnosed with Parkinson's disease (PD). In patients with PD, impairments in cognitive-linguistic function are most apparent at higher levels of discourse requiring more complex cognitive-linguistic processes. This manifests itself at the level of reading comprehension. In patients diagnosed with Parkinson's disease, a relationship has been found between disease severity, memory, language and text comprehension (Murray & Rutledge, 2014). There are mixed results in the assessment of reading abilities in patients diagnosed with dementia. It appears that in dementia, reading skills are essentially unimpaired or impaired to a much lesser extent compared to the global cognitive deficit that appears (Noble, 2000). Some hypotheses suggest that impairments in processing in sentence and text comprehension are mainly due to impairments of working memory (Liu, Wang, Wang & Sun, 2019). Similar results have been obtained for Friedreich's ataxia, a rare genetic mutation in which mild impairments in cognitive processes are also detected in reading abilities (Sayah et al, 2018).

It can be seen that the reading ability system is a highly complex process, and therefore the study of reading processes is a complex issue for both typically and atypically developing learners and adults. Theoretical knowledge and the results of empirical research will help to make the assessment of reading processes as comprehensive as possible. Based on the above, some key aspects can be identified to help design a comprehensive assessment of reading as a cognitive ability system. Phonological awareness and the closely related grapheme-phoneme correspondence are of particular importance, similarly to word reading skills, which determine the correct functioning of later stages of text processing. And in text comprehension, cognitive processes such as mental models of the text, inference, prior knowledge and working memory are also of particular importance. Taking all these into consideration, it is possible to comprehensively investigate the mechanisms involved in reading.

Aim of the study

Damage to the brain networks involved in reading, or their inadequate development, can result in impaired reading functions. This may be manifested in the failure of the grapheme-phoneme correspondence, or in the impairment of the processes necessary for word reading, or may affect impaired text comprehension. Among acquired disorders affecting the central nervous system, a common symptom is a deficit in reading, which may be a manifestation of a more global cognitive impairment, but in many cases is a leading symptom of the deficits in language processes (Cherney, 2004; Coslett, 2012; Denes, Cipolotti & Zorzi, 1998; Murray & Rutledge, 2014; Noble, 2000; Liu, Wang, Wang & Sun, 2019; Smith & Ryan, 2020; Smith et al., 2018; Wollams, 2015). Our aim was to develop an assessment to measure the reading abilities of individuals diagnosed with adult acquired cognitive impairment, thereby expanding the range of diagnostic tools used in the clinic to contribute to a comprehensive assessment of the pre-therapy cognitive ability profile. An accurate diagnosis is a

fundamental pillar of the therapy planning, and well-designed, individualised therapy is essential to ensure that the patient achieves the best possible quality of life at the end of the rehabilitation process.

To allow a more accurate differentiation between patients' performance, a more specific test procedure for reading across multiple functions and a related scoring system were designed. To develop the scoring system for the test, data were collected from healthy individuals, and the composition of the Hungarian population was used as a basis for defining the parameters of the participants. In developing the scoring system for the Adult Reading Test, our aim was to determine what is considered to be normal performance on each task, based on age and education, and to determine the degree of impairment as a function of scores and reaction times. In this manner, a complex scoring system is established that can be informative not only for diagnostic work but also for exploratory research.

Research questions

The purpose of the data analysis was to develop a comprehensive and detailed test scoring system. For this purpose, differences between groups were explored and psychometric indicators related to the test were analysed. The psychometric indicators of the Adult Acquired Reading Assessment were analysed first. The following research questions were related to this:

Q1: Do the items that comprise the test all achieve an acceptable Cronbach's value of 0.6? (Gliner et al., 2017; Józsa & Józsa, 2020).

Q2: Regarding the strength of correlations between items, what is the correlation between the items? Are there redundant items?

In order to determine which parameters should be used to design the scoring system, the correlations between the groups were identified and analysed then. In this context, the data analysis was structured around the following research questions:

Q3: Is there a gender difference between participants (women vs. men)?

Q4: Is there a significant difference between participants by age group (18-29, 30-39, 40-49, 50-59, 60-69, over 70)?

Q5: Is there a significant difference between participants by educational level (primary, secondary, higher)?

Methods

The Adult Acquired Reading Assessment consists of a total of 10 tasks based on phonology, word reading, lexicon and word processing (Table 1.).

Table 1. Adult Acquired Reading Assessment structure

Adult Acquired Reading Assessment	
Grapheme-to-phoneme conversion	vowels (26)
	consonants (28)
Word reading	syllables (24)
	two-letter words (24)
	complex words (50)
	pseudowords (25)
Lexicon	Picture-word matching (20) 10 noun, 10 verb
	lexical decision (50)
	grammatical/agrammatical sentences (20)
Text comprehension	text comprehension (21) – explicit (10) and implicit (11) information processing

The grapheme-phoneme conversion was measured by reading vowels (n=26) and consonants (n=28). The stimuli were selected from a set of reading tasks for school-age children (Juhász, 2003). To assess lexical language level, two main sets of tasks were developed: word reading and lexical access. To investigate word reading, we set up four tasks, two of which involved reading words with a semantic content and two without a

semantic content. Word reading with a semantic content was measured by presenting two-letter words (n=24) and stimuli including compound words (n=50) ranging from single to multi-syllable words. The selection of syllables and words used in the study was based on the reading assessment worksheets for school students by Ildikó Meixner (Juhász, 2003) and on the task book of Sipos (2013). In selecting the stimuli, we also considered word frequency, using the word frequency list published by the Hungarian National Text Repository. For stimuli with no semantic content, the task was to read aloud syllables (n=24) and pseudowords (n=25). The pseudowords were generated using a computer program, taking into account Hungarian phonotactic rules and word frequency indicators.

Lexical access measured the access to lexical information. Three tasks included picture-word matching, word-nonword lexical decision task and grammatical/agrammatical sentences. In the picture-word matching task, participants had to select the word from three options corresponded to the picture shown in the middle of the screen. One of them was the correct answer, the second one was similar to the target word but with a phonological error, and the third one was a distractor with some semantic connection to the target word. The task showed nouns (n=10) and verbs (n=10), which were also selected from the word frequency list published by the Hungarian National Text Repository, which included frequent, less frequent and rare words.

For the word-nonword lexical decision task, a total of 25 target words of 1-5 syllables were selected from each word class (noun, verb, adjective, pronoun, adverb), based on the word frequency list mentioned above. For each of these target stimuli, a pseudo-pair was generated using Neurolinguistics Research 1.1 (also part of the program we created), taking into account Hungarian phonotactic rules, syllable count and CVC (vowel-consonant correspondences). Thus, in total, this task contained 50 stimuli (25 words, 25 pseudowords). During the task, participants had to judge whether the stimulus on the screen was a real Hungarian word with a meaning. If yes, they clicked on the tick icon, if no, they clicked on the x. As the aim of this task was to measure lexical access to the words, participants were not required to read out the presented stimuli.

In the case of grammatical/agrammatical sentences, the aim was to investigate the processing of sentence-level information by presenting participants with morphosyntactically correct and incorrect sentences. Their task was to decide whether the presented stimulus is correct or incorrect. The sentences were structured using the most typical case phrases for the Hungarian language (Kiefer, 2011), which were: accusativus (-t), dativus (-to, -from), instrumental (-with, -with), causalis-finalis (-for), translativus-factitivus (-to, -to), inessivus (-in, -in), supressivus (-on, -on, -on), adessivus (-at, -at), allativus (-to, -to, -to), ablativus (-from, -from), terminativus (-to). As before, patients were asked to click on the tick if the sentence presented was correct, or on the x if it was incorrect.

The last part of the reading assessment was about text comprehension, for which we had chosen an open access text published by PIRLS (Progress in International Reading Literacy Study). Some of the text-related questions had been adapted and supplemented to be as specific as possible for the adult population. The original assessment of the text comprehension was extended to allow for separate interpretation of explicit (n=10) and implicit (n=11) information processing.

Participants

Once the structure of the Adult Acquired Reading Assessment Test had been established, it was necessary to develop a scoring system for the test. To determine what would be considered normal performance in terms of specific parameters, first, it was first necessary to measure the test procedure on a large sample of healthy people without a neurological disease. First, we created the Neurolinguistics Research App. on which the Adult Acquired Reading Assessment was available with the help of a software developer. The app was accessed via a website, after entering an email address and associated password, the application provided an interface where it is possible to enter the participant's details (gender, age group, education) and select the task to run. The software also measured the reaction time for the grapheme-phoneme conversion, word reading and lexicon tasks, and records the correctness of the option chosen by the participant for the lexicon tasks (picture-word matching, word-word lexical decision, grammatical/agrammatical sentences).

We involved college students in a large sample measurement of the Adult Acquired Reading Assessment, and it was their task to assess the reading of participants based on given parameters and return this data to us. Firstly, based on a prior agreement with the Institute of Teacher Education of the Faculty of Education and the Institute of Psychology of the Faculty of Psychology of the University of Szeged the research was carried out with the ethical approval No. 60/2022-SZTE RKEB after prior written information and consent of the heads of

the institutions and the dean. Participation in the data collection was voluntary and counted towards course completion. An educational guide was provided to the students on the research, the test design and the use of the program. The educational guide and the protocol for the reading test were available to them. Before the start of the research, the students who participated in the data collection were given the program-generated passwords needed to log into the program via their e-mail address.

Sampling was organised by quota sampling. Based on the latest census data from the KSH, the required number of persons was calculated by gender, education and age, in order to represent the proportions of the Hungarian population. The students had to upload all this into an Excel file accessible via a Google document, and their primary task was to search for persons based on the given parameters and take the assessment. The criterion for inclusion in the study was that no neurological or psychiatric conditions should be listed in the participant's medical history. The data were entered into a central server to which only the research managers had access, thus ensuring the anonymity of the students and subjects. Students were required to sign a consent form with each subject for ethical approval of this research, and students also signed a confidentiality agreement related to the research itself. The completed reports were sent by the students in scanned form to a central email address, which was also only accessible to the research supervisors. Data collection took place between 2 March and 6 May 2022. During the data collection, students were consulted in person and online on several occasions.

Once the data collection period was over, data was received in two ways, with responses being recorded on paper and reaction times being recorded online. Accordingly, students who participated in the survey were required to fill in a report for each of the cases, which was scanned and sent to a central e-mail address together with the consent forms. The information on reaction times was available on the server of the Neurolinguistics Research App. The protocols were manually coded one by one. The reading task was scored in advance, the participant scored 1 point for each correct answer. The protocols and data on reaction times were recorded in an excel file.

A total of 480 healthy adults with no neurological or psychiatric disease took part in the survey: 269 were women and 201 were men. The breakdown by age group and education level was based on the latest KSH census data. In terms of age groups, a total of 139 persons aged 18-29, 75 aged 30-39, 76 aged 40-49, 84 aged 50-59, 60 aged 60-69 and 46 aged 70 and over were included in the survey. In terms of educational level, a three-tiered scale was used: primary education was defined as those with the highest level of education of eight years of primary school, secondary education as those with a school-leaving certificate and/or vocational diploma, and higher education as those with a university degree or higher. On this basis, a total of 87 general qualifications, 278 secondary qualifications and 105 tertiary qualifications were included in the survey (Table 2.).

Table 2. Number of participants in the large sample survey by gender, age and educational attainment

Age group	FEMALE			MALE			SUM
	Educational level			Educational level			
	Primary	Secondary	Higher	Primary	Secondary	Higher	
18-29	9	47	21	11	44	7	**139**
30-39	7	23	12	3	20	10	**75**
40-49	7	28	9	5	21	6	**76**
50-59	6	25	12	6	27	8	**84**
60-69	7	29	7	7	7	3	**60**
70-	15	10	5	4	7	5	**46**
SUM	**51**	**152**	**66**	**36**	**126**	**39**	**480**

Results

Psychometric indicators of the Adult Acquired Reading Assessment

A total of 480 participants' data were used to analyse the test's reliability indicators. In this case, the Cronbach's α value is 0.70, i.e. the test reliability is adequate, as values above 0.6 are considered acceptable for this type of measurement (Gliner et al., 2017; Józsa & Józsa, 2020). The reliability indicators were also analysed per task, and in general, the reliability of all tasks was found to be adequate (0.66-0.76). For the tasks measuring grapheme-phoneme conversion, the reliability values were similar. For the word reading tasks, there was less

variance, with the highest reliability value for the reading of two-letter words (0.70) and the lowest for the reading of pseudowords (0.64). For the lexical access tasks, a higher value was obtained for the word-nonword lexical decision task (0.76). A similar acceptable value was obtained for the text comprehension task (Table 3.).

Table 3. Based on the large sample measurement, the reliability indicators of the Adult Acquired Reading Assessment

Task		Cronbach-α
Grapheme-to-phoneme conversion	vowels (26)	.67
	consonants (28)	.68
Word reading	syllables (24)	.67
	two-letter words (24)	.70
	complex words (50)	.65
	pseudowords (25)	.64
Lexicon	Picture-word matching (20) 10 noun, 10 verb	.65
	lexical decision (50)	.76
	grammatical/agrammatical sentences (20)	.66
Text comprehension	text comprehension (21) – explicit (10) and implicit (11) information processing	.69

Validity was then tested by analysing the correlations between the tasks. The results of the analyses showed significant correlations between all tasks except for reading comprehension and syllables and two-letter words. In terms of the strength of the correlations, the correlations were mostly medium to weak (0.2-0.5), which means that although there was a correlation between the different tasks of the reading assessment, the different tasks were testing different areas. Based on these results, it seems that all tasks of the Adult Acquired Reading Assessment were necessary for an overall investigation of reading, and that the individual tasks were not redundant (Table 4.).

Table 4. Correlations between the tasks in the Adult Acquired Reading Assessment

Tasks	**Vowels**	**Consonants**	**Syllables**	**Two-letter words**	**Complex words**	**Pseudowords**	**Picture-word matching**	**Word-nonword lexical decision**	**Grammatical/ agrammatical sentences**	**Text comprehension**
Vowels	-	.40	.42	.24	.30	.26	.18	.21	.15	.15
Consonants	.40	-	.40	.20	.30	.23	.18	.16	.18	.11
Syllables	.42	.40	-	.33	.31	.27	.18	.20	.18	n.s.
Two-letter words	.24	.20	.33	-	.21	.21	.11	.10	.09	n.s.
Complex words	.30	.30	.31	.21	-	.30	.31	.24	.21	.27
Pseudowords	.26	.23	.27	.21	.30	-	.36	.18	.22	.16
Picture-word matching	.18	.18	.18	.11	.31	.36	-	.34	.26	.27
Word-nonword lexical decision	.21	.16	.20	.10	.24	.18	.34	-	.26	.19
Grammatical/agrammatical sentences	.15	.18	.18	.09	.21	.22	.36	.26	-	.20
Text comprehension	.15	.11	n.s.	n.s.	.27	.16	.27	.19	.20	-

Regarding the internal structure of the test, it can be seen that the strength of correlation between tasks varied according to the task groups. In general, the simpler, phoneme- and word-level tasks, at the beginning of the test, showed weaker correlations than more complex tasks. The opposite was true for lexical, sentence and text level tasks, where increasing correlations were found between tasks requiring more complex, higher level cognitive-linguistic operations. The results showed that almost all tasks were correlated, with weak or medium strength, meaning that all tasks type was necessary. This suggests that the structure of the Adult Acquired

Reading Assessment seems to be appropriate. Then, we developed the scoring system for the test, which is described in the next section.

The primary goal of developing the reading assessment test was to provide a diagnostic tool to determine whether an adult patient had a difference in scores and reaction times in any function compared to what would be expected based on his age and education. In addition to this, however, as the aim was to develop a diagnostic tool, the focus was not only on establishing the fact of a difference, but also to allow for a more specific analysis. More specifically, we attempted to determine the severity of the discrepancy, i.e. whether it was mild, moderate or severe in relation to the performance expected at a given age and the level of education. First we analysed the data of the healthy individuals who completed the survey in terms of scores and reaction times. Before the scoring system was developed, pre-testing had been carried out to determine which factors should be used to design the normative ranges. These results are presented below.

The IBM SPSS Statistics 23 statistical software was used for the analyses, with 95% confidence intervals in all cases. During data collection, three factors were noted for each participant: participant gender, age and education level. In order to determine which factors to adjust the normative ranges along, we analysed whether there were significant group-level differences based on these factors. First, the sample distribution was analysed using Kolmogorov-Smirnov test. This showed that the sample did not follow a normal distribution, so non-parametric tests were used.

First, for the scores, we analysed whether there was a difference in the sample by gender, using the Mann-Whitney U-probe. The only significant difference was found for reading two-letter words (Z=-2.46; p=.014). No significant differences were found for vowels (Z=-0.46; p=.639), consonants (Z=-0.07; p=.944), syllables (Z=-1.27; p=.201), complex words (Z=-0.01; p=.987), pseudowords (Z=-1.30; p=.192), picture-word matching (Z=-1.13; p=.255), word-nonword lexical decision (Z=-1.85; p=.064), grammatical/agrammatical sentences (Z=-0.46; p=.642) and text comprehension (Z=-1.07; p=.284).

One-way analysis of variance (ANOVA) was used to test for differences by age group, and Dunett's T3 and Tukey's B tests were used as post-hoc tests. We explored which age groups differed in their performance on each reading task. Significant group differences were obtained for vowels (F=3.52; p=.004), syllables (F=3.70; p=.003), pseudowords (F=5.54; p<.001), picture-word matching (F=7.10; p<.001), grammatical/agrammatical sentences (F=3.30; p=.006) and text comprehension (F=2.97; p=.012). Post-hoc test results showed that there was a significant difference between the performance of 18-29 and 60-69, 18-29 and 70+, 50-59 and 70+, 30-39 and 60-69, and 30-39 and 70+ (Table 5.).

Table 5. Results of the age group analysis

Tasks	Age group						Analysis of variance		Post-hoc tests
	18-29 mean (SD)	*30-39 mean (SD)*	*40-49 mean (SD)*	*50-59 mean (SD)*	*60-69 mean (SD)*	*70+ mean (SD)*	*F*	*p*	
Vowels	25.83 (.94)	25.76 (.74)	25.74 (.92)	25.81 (.64)	25.22 (1.47)	25.40 (1.75)	3.52	.004	{1}<{5}<{6} {2}<{5}<{6} {4}<{5} {4}<{6}
Consonants	27.89 (.42)	27.83 (.64)	27.83 (.70)	17.83 (.58)	27.60 (1.05)	27.69 (1.32)	1.55	.172	
Syllables	23.75 (.66)	23.59 (.98)	23.71 (.84)	23.70 (.88)	23.16 (1.29)	23.38 (1.38)	3.70	.003	
Two-letter words	23.93 (.31)	23.92 (.27)	23.88 (.58)	23.94 (.23)	23.78 (0.61)	23.80 (.69)	1.51	.183	
Complex words	49.49 (1.13)	49.57 (1.26)	49.30 (2.38)	49.64 (.70)	48.96 (2.39)	48.87 (2.93)	2.02	.073	
Pseudowords	23.90 (1.65)	23.16 (3.00)	23.53 (1.78)	23.67 (1.31)	22.50 (3.71)	21.60 (3.50)	5.54	<.001	
Picture-word matching	19.62 (.81)	19.67 (.75)	19.29 (1.65)	19.42 (1.17)	18.60 (2.31)	18.71 (1.74)	7.10	<.001	
Word-nonword lexical decision	48.52 (3.64)	48.82 (1.99)	48.50 (3.71)	48.67 (4.09)	48.30 (2.72)	48.36 (1.73)	.21	.956	
Grammatical/agrammatical sentences	19.06 (1.13)	19.04 (1.82)	18.33 (2.11)	18.71 (1.66)	18.48 (1.95)	18.22 (2.23)	3.30	.006	
Text comprehension	20.00 (1.58)	19.79 (1.70)	19.34 (2.18)	19.38 (2.23)	18.92 (2.76)	19.31 (1.99)	2.97	.012	

We also analysed the effect of educational level on reading performance, dividing participants into three groups: primary, secondary and higher education. One-way analysis of variance (ANOVA) was also run to explore differences, and Dunett's T3 and Tukey's B tests were applied for post-hoc tests.

The results showed significant differences for all tasks as a function of educational level, i.e. the groups' performance differed for vowels (F=8.99; p<.001), consonants (F=17.13; p<.001), syllables (F=16.77, p<.001), two-letter words (F=17.22; p<.001), complex words (F=43.17, p<.001), pseudowords (F=20.23, p<.001), picture-word matching (F=22.56; p<.001), word-nonword lexical decision (F=9.82, p<.001), grammatical/agrammatical sentences (F=17.13, p<.001) and text comprehension (F=21.57, p<.001) tasks (Table 6.).

Table 6. The impact of educational level on reading performance

Tasks	Education level						Analysis of variance		Post-hoc tests
	Primary		*Secondary*		*Higher*				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	
Vowels	25.28	1.55	25.76	0.98	25.87	.53	8.99	<.001	{1}<{2} {1}<{3} {2}<{3}
Consonants	27.41	0.34	27.90	0.52	27.93	.28	17.13	<.001	
Syllables	23.11	1.36	23.67	0.87	23.87	.55	16.77	<.001	
Two-letter words	23.66	0.83	23.94	0.28	23.98	.13	17.22	<.001	
Complex words	47.93	3.40	49.66	0.89	49.85	.38	43.17	<.001	
Pseudowords	21.64	3.59	23.59	1.96	24.11	1.52	20.23	<.001	
Picture-word matching	18.49	1.85	19.47	1.30	19.70	.79	22.56	<.001	
Word-nonword lexical decision	47.21	4.73	48.75	3.11	49.14	1.54	9.82	<.001	
Grammatical/agrammatical sentences	17.82	2.32	18.85	1.50	19.19	1.58	17.13	<.001	
Text comprehension	18.44	2.92	19.66	1.82	20.27	1.08	21.57	<.001	

The post-hoc tests revealed significant differences between the scores of people with primary education and those with secondary and higher education on all tasks. There were significant differences between participants with secondary and higher education on three tasks: syllables (secondary education: M=23.67; SD=.87; higher: M=23.87; SD=.55) and reading words (secondary: M=49.66; SD=.89; higher: M=49.85; SD=.38), and in the text comprehension tasks (secondary: M=19.66; SD=1.82; higher: M=20.27; SD=1.08).

After this, we also analysed reaction times data. Due to the complexity of the task and its length, we did not measure reaction times for text comprehension alone. First, similar to the scores, gender difference was tested using a Mann-Whitney U-probe. There were no significant differences between groups on any of the tasks, i.e. vowels (Z=-1.52; p=.127), consonants (Z=-0.82; p=.409), syllables (Z=-0.73; p=.465), reading two-letter words (Z=-1.34; p=.179), reading complex words (Z=-0.30; p=.762), reading pseudowords (Z=-0.52; p=.597), picture-word matching (Z=0.66; p=.503), word-nonword lexical decision tasks (Z=-0.27; p=.782) and grammatical/agrammatical sentences (Z=-0.92; p=.354) revealed no significant differences between males and females.

For the analysis of reaction times, we also applied a one-way analysis of variance (ANOVA) to explore differences between age groups. Dunett T3 and Tukey-B tests were also used here for post-hoc tests. Only the picture-word matching task showed significant differences between age groups (F=4.06 p<.001). Post-hoc tests showed that the 18-29 age group (M=3293.67 ms; SD=1358.11 ms) completed the task significantly faster than the 50-59 age group (M=3962.80 ms; SD=1506.46 ms) and the 70+ age group (M=2610.10 ms; SD=1333.27 ms). There were no significant group differences for vowels (F=0.89; p=.482), consonants (F=0.43; p=.825), syllables (F=0.77; p=.566), two-letter words (F=1.15; p=.331), reading complex words (F=0.19; p=.965), pseudowords (F=0.449; p=.814), word-nonword lexical decision (F=1.41; p=.217) and grammatical/agrammatical sentences (F=0.95; p=.445).

For reaction times, we also analysed the performance of participants as a function of educational level. There were significant differences among the groups in the picture-word matching task (F=9.22; p<.001). Participants with primary education spent more time on the task (M=4259.67 ms; SD=2182.55 ms) than participants with secondary education (M=3608.17 ms; SD=1542.72 ms) and higher education (M=3669.97 ms; SD=1647.87 ms). No significant differences were found for vowels (F=0.30; p=.736), consonants (F=1.67;

p=.189), syllables (F=0.76; p=.466), two-letter words (F=1.73; p=.066), complex words (F=1.78; p=.175), pseudowords (F=1.14; p=.319), word-nonword lexical decision (F=1.24; p=.289) and grammatical/agrammatical sentences (F=1.37; p=.25).

The development of a scoring system for the Adult Acquired Reading Assessment

To summarise the above mentioned data, we have analysed the effects of gender, age and education on scores and reaction times for the data received. Some conclusions can be drawn from these results. It can be seen that there were no significant differences between genders (women vs. men) in terms of either scores or reaction times. However, significant group differences by age and educational level were found for several reading tasks, with the effects being most pronounced for scores. Since we aimed to develop a uniform scoring system, we concluded that the normative ranges for both scores and reaction times should be developed on the basis of both age ranges and educational level.

Data received in the large-sample survey were from healthy adults with no neurological and/or psychiatric pathology, meaning that in many cases they only lost a few points on some tasks. However, the pre-tests showed that there were significant differences in performance across age groups and educational levels. In establishing the scoring system for the assessment, the data were primarily analysed in percentiles, and in each case the standard deviation, means and medians, frequency indicators and minimum and maximum values were analysed. On the basis of these results, we concluded that the interquartile range, i.e. the difference between the first and third quartile of the data (Q3-Q1), was the range that could be defined as the normal performance for a given age and educational level. The method of defining the normal range by the interquartile range is a commonly used method in the international literature, mainly to mark the normal range of reaction times. Based on the characteristics of the data in question, the normal range was often referred to as the interquartile range of 1.5 (LaValle, 2019; Loucks & Nil, 2006; Bradford et al., 2009; Benesch et al., 2000). In determining the interquartile range for the data we analyzed, we also considered several other indicators. Taking all these into account, the ranges for both scores and reaction times were defined as shown in Table 7.

Table 7. Mathematical background to the design of ranges

Ranges	**Method of calculation**	
	Scores	*Reaction times*
normal	100%- 1 interquartile range	Q3 + 1 interquartile range
mild	100%- 2 interquartile range	Q3 + 2 interquartile range
moderate	100%- 3 interquartile range	Q3 + 3 interquartile range
severe	below 100%- 3 interquartile range	above Q3 + 3 interquartile range

For the scores, we defined the maximum score available in a given task and scores less than 1 interquartile range as the normal range. The threshold for the mild impairment category was defined as a score up to the maximum score and two interquartile ranges below the maximum score, the moderate impairment category defined as a score below three interquartile ranges below the maximum score, and the severe category defined as a score below three interquartile ranges below the maximum score. For reaction times, the zones were constructed using the interquartile range given for the upper quartile. This means that the normal category was represented by the upper quartile plus one interquartile range, the mild category by the upper quartile plus two, the moderate category by the upper quartile plus three and the severe category by reaction times of the upper quartile plus three interquartile ranges. In all cases the values were in milliseconds.

The ranges based on age groups and educational level were recorded in an excel table. The software developer recorded the reaction time data in the Neurolinguistics Research App., as well as the scores of the tasks whose results were recorded by the software (these were picture-word matching, word-nonword lexical decision and grammatical/agrammatical sentences). It allowed the application to evaluate the participant's results immediately after the Adult Acquired Reading Assessment was completed and to give feedback on whether there was a discrepancy and, if so, to what extent.

Discussion

Reading is a crucial part of modern daily life, so its inadequate development, or the dysfunction of an already developed ability system, affects the quality of life of the individual. Abnormalities in reading can occur not only due to atypical development but also as a result of neurological damage acquired in adulthood. The aim of our study was to establish a test procedure to specifically diagnose adult acquired reading disorders. Based on the national and international literature on atypical reading disorders in childhood and acquired reading disorders in adulthood, we have compiled a reading assessment instrument to specifically diagnose acquired reading disorders.

The scoring system for this assessment was developed based on the results of a large sample survey of healthy populations without a neurological disease. Our aim was to provide a unique way to determine not only the fact of disorder but also its severity. As a first step in developing a scoring system for the test, we investigated which parameters affect reading in a healthy adult population. Data from 480 adults were collected in a large sample survey. In order to reproduce as accurately as possible the composition of the Hungarian population, the number of participants was determined by gender, age group and educational level based on the latest census data of the Hungarian Census Service (KSH). The surveys were recorded via the Neurolinguistics Research App for the Adult Acquired Reading Assessment. The data received included the scores obtained on the test and the reaction times produced during the tasks. The scores and reaction times were used to calculate the expected thresholds for performance on a given task based on age and educational level. Since we intended our assessment to provide information not only on the fact of discrepancy but also on its severity, we designed a scoring system of the test based on percentile values and the associated interquartile range, frequency indicators, minimum and maximum values after thorough analysis of the data after the pretesting.

A total of five research questions were defined for the study in relation to data analysis. First, the psychometric indicators of the Adult Acquired Reading Assessment were explored. It was assessed whether the recommended Cronbach's alpha of 0.6 (Q1) was obtained for each item. The results showed that the reliability was acceptable for all items (0.64-0.76), which means that the reliability of the Adult Acquired Reading Assessment is appropriate. To determine the validity of the measurement, the strength of correlations between each tasks was analyzed (Q2). Medium to weak correlations were found, indicating that the test does not contain a redundancy element. All this seems to indicate that the structure of the assessment is appropriate.

In order to develop a scoring system for the test, differences between groups were also identified. In this context, gender differences were first explored (Q3). The results showed that there were no significant differences by gender (women vs. men), and thus gender differentiation seemed irrelevant when designing the assessment scoring system. It was also investigated whether there were significant differences between participants by age group (Q4). There were differences between several groups and therefore it was relevant to take age groups when designing the scoring system for the test. The effect of educational level on reading performance was also analysed, i.e. whether there were group differences by educational attainment (Q5). The results showed that educational qualification was a significant determinant of reading performance for all tasks, i.e. educational level was also a determining factor when designing the assessment scoring system.

Therefore, this scoring system was developed on the basis of age groups (18-29, 30-39, 40-49, 50-59, 60-69, 70+) and educational level (primary, secondary, higher).

We aimed at constructing our test in such a way that it would provide information not only on the fact of the difference but also on its severity, so after a thorough analysis of the data after the pre-tests, we developed its scoring system based on the percentile values and the corresponding interquartile range, the frequency indicators, the minimum and maximum values. This has resulted in a complex assessment instrument for objectively measuring reading problems in adult acquired cognitive-linguistic disorders. The developed scoring system makes the Adult Acquired Reading Assessment a valuable tool for both diagnostic and exploratory research, thus supporting clinical practice.

Conclusions

The emergence of reading as a cultural phenomenon in society has become a key factor in modern everyday life. Due to the multidisciplinary nature of reading research, there is a large body of empirical research on the different reading processes from preschool to later life, as well as on the cognitive and sociocultural factors involved. The structure of the adult reading test and its detailed scoring system allow for a comprehensive assessment of reading processes. This not only facilitates clinical practice but also contributes to a deeper

insight into reading processes. Although the approaches of the different scientific field disciplines seem to differ, the results of findings from pedagogical, psychological, cognitive neuroscience, social science, sociological and related studies interact. The transfer of knowledge from these findings across disciplines is the way forward for reading research.

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