# Dyslexia from special education and neuroscientific perspective: selected aspects of the first stage of the research

(scientific paper)

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***Abstract:*** *Currently, dyslexia is a frequently discussed topic, which is central in many fields of science, such as special education, speech therapy, psychology, linguistics, or neuroscience. The report is a part of the international research which interconnects all the fields mentioned above. The paper presents a comparison of psychological and special-educational evaluation of adult university students/university alumni with dyslexia and without it. In this part of the research, 27 participants were assessed by a series of six tests. The data obtained were processed in IBM SPSS Statistics 23 with the help of Multivariate analysis of variance (MANOVA). The results showed that group with dyslexia varied in their test performance aimed at reading and reading abilities, and there were no significant intelligence, attention or short-term memory differences. At the end, the report includes partial data taken from functional magnetic resonance imaging (fMRI).*

***Keywords:*** *dyslexia, adult, reading, student, neuroscience, special education*

## 1 Introduction

Dyslexia is a specific developmental learning disorder which has an impact not only on the school performance, but also on other aspects of life (Mortimore & Crozier, 2006). According to the International dyslexia association (IDA), dyslexia is defined as *„a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can*

*impede growth of vocabulary and background knowledge*" (Lyon & Schaywitz, 2003, p. 2). Even though the term dyslexia is still used, the International Classification of Diseases and Related Health Problems, 11th revision, presents dyslexia as *a developmental learning disorder with impairment in reading* (ICD 11 International Classification of Diseases 11th Revision, 2018).

There are several theories dealing with the origins of development of reading difficulties in people with dyslexia, such as magnocellular, cerebellal or phonological theories (Vellutino at al., 2004; Jošt, 2011). Phonological deficits can be demonstrated in some of the functional data which show the differences in the activation of brain regions in dependance on the type of the text read (if it is a word/a pseudoword), and also the differences between the groups with and without dyslexia in the tests aimed at the phonological processing of information without reading a text (e.g. some of the subtests of DysTest assessment battery described below [Cimlerová et al., 2014]). There are also motor differences in eye movement while observing a non-text objects (e.g. a moving point, graphic symbols, etc.) in people with dyslexia compared to normal readers (Vyhnálek et al., 2006; Lukášová et al., 2016).

Throughout the educational process, the specific reading disorder is observed in particular features of learning the reading skills. Even though there are various compensatory strategies which help to deal with these difficulties applied at school, dyslexia impacts the lives of adults too. Nowadays, as there are high demands on reading and written communication, some less serious forms of dyslexia may be diagnosed later in life when those demands increase (Reid & Kirk, 2000). Besides, psychological impact of this specific disorder on adults was also described (Kejřová & Krejčová, 2015). These problems may include a lower level of self-confidence as a result of former recurring failures, etc. (Carawan et al., 2016).

The following part presents partial outputs of the project focused on the university students and alumni. The group with dyslexia and a control group with normal readers were assessed by a group of tests aimed at reading skills and the level of various partial cognitive functions as well as undergone measuring in functional magnetic resonance (fMRI) and eye tracking. The data are supposed to enable the comparison with commonly cited foreign research and to contribute to the development of knowledge considering the specific reading disorder in the context of Czech language environment. Moreover, the research also examines the brain regions which are activated in the process of reading. Among these, we can mainly name the visual parts of occipital cortex, the fusiform gyrus in the left hemisphere, where our Visual Word Form Area is located, and some other parts of superior and middle temporal gyrus, as well as the prefrontal cortex (Waldie et al., 2017). Other research has shown the differences in the brain activation of dyslexic people when reading. A significantly lower engagement of some brain regions of the dyslexic people when reading was found too; these were, for example, fusiform gyrus and intraparietal sulcus in the

left hemisphere (Maisog, 2008). Current literature describes considerably higher engagement of other brain areas whose function can be compensatory. Pollack et al. (2015) points out, for example, some of the right hemisphere areas (frontal gyrus inferior or dorsolateral cortex).

For the potential comparison and evaluation of the functional data, it was necessary to make profiles of the participants with the help of available assessment material. The psychological tests of 27 participants and their evaluation will be described in the text. These are preliminary results of the project lasting from 2018 to 2019.

## 2 Material and Methods

There were 27 participants included in the research, 14 of them with dyslexia and 13 of them within a normal range reader (control group). All of the participants were or have been university students, their mother tongue was Czech, and they had no history of being diagnosed with attention disorder. The average age of the group was 23,7 with the age span 19–31. The potential participants were addressed via university centres for students with special needs in Olomouc (UPOL), Brno (VUT) and Prague (UK), social networking sites and the database of potential participants of the Laboratory of multimodal and functional imaging (CF MAFIL, CEITEC MU, Brno).

A series of six tests was used for extracting and consequent comparison of the profiles of individual participants and groups. The tests were conducted with every participant individually, always in the same order and the whole assessment procedure lasted approximately1 hour.

The series included the following tests:

1. The Adult reading history questionnaire (Jira, 2014);
2. Digit span – adapted from WAIS-III (Wechsler, 2010);
3. The attention test – the Brazilian version of Teste de Atenção por Cancelamento with Czech instructions (Seabra & Dias, 2012);
4. The test of rapid automatized naming – taken from CTOPP, subtest RAN (Rapid automatized naming) (Wagner et al., 1999);
5. TIP – Non-verbal intelligence test, progressive matrices – a subtest taken from KIT (Říčan & Laciga, 2017);
6. Three subtests from DysTest – aimed at the perception of familiar phonemes (blending and segmenting words, backword repetition of words), reading of pseudowords (text Latyš) and phonological competence (Cimlerová et al., 2014).

The first test applied is the Adult reading history questionnaire (Lefly & Pennington, 2000; Jira, 2014). It is a self-report screening tool containing 23 questions. In each

question, the participant determines his agreement or disagreement with the assertion given on the scale 0 to 4. The questions are mostly focused on the participant's current experience with reading (how often he/she reads, whether he/she reads at work or in his/her leisure time, whether any difficulties with reading occurred in the childhood) and on his/her performance at school. Due to the questionnaire's characteristics, we are able to obtain a subjective evaluation of participant's own difficulties. Based on that, we can only determine the existence or non-existence of reading difficulties. Nevertheless, the questionnaire proved to be a reliable tool in former research, and it could represent one of the most accurate diagnostic tools for the adults who often use compensatory reading strategies (Lefly& Pennington, 2000; Jira, 2014).

The second test used is the digit span test. It is a part of WAIS-III which is applied to evaluate participant's cognitive abilities. This test mainly evaluates the level of short-term and working memory. It is divided into two parts. In the first part, the participant's task is to repeat chains of digits. This part contains 8 tasks whose difficulty increases with the length of digit chains (from 2 to 9 digits). In the second part, the participant should repeat the digit chains backwards.

The third is the attention test, which was adapted from the Brazilian test Teste de Atenção por Cancelamento (TAC). The participant works with symbols depicted on a sheet. Out of those depicted on the page, his/her task is to cross out symbols depicted in the upper part. The test includes three parts – in the first one, the participant crosses out one symbol, in the second part, there are two symbols, and there is a different symbol for each line in the third part. The evaluation criteria are the time needed to complete each part of the test and the number of omitted symbols and symbols which were marked incorrectly. The aim of the test is to assess the level of attention.

Another part of the series of tests is the Rapid automatized naming (RAN) test which is included in the CTOPP (Comprehensive test of phonological processing). The test is divided into four parts. In each part, the participant should name colours/objects/digits/letters, which he/she can see on the page in front of him on separate lines as fast as he/she can. The administrators measure the time in which the participant both names everything on the page and evaluates correctness. The ability of rapid automatized naming of people with specific reading disorder often appears to be deficient (Wolff, 2013). Regarding scientific applicability of the RAN subtest, all of its parts have been used despite of the fact that the naming of colours and pictures is standardised for children only.

The fifth test included is the Test of intellectual potential (TIP), which is a part of KIT (the Short test of intelligence [Říčan&Laciga, 2017]). This test was included with the purpose of estimating an approximate comparison of the participant's level of intelligence. The TIP was chosen with due to its short administration and nonverbal nature. The results of a verbal test could be affected by deficient reading abilities and

the time limit for pursuing the reading tasks. In the TIP a participant has to choose the right symbol from the symbols given which belongs to the logical picture chain. According to correct answers, it is possible, with the help of a PC application, to obtain an approximate value of the IQ. However, it is necessary to consider this value to be only approximate due to its extraction from the original series of tests.

Besides the above mentioned, we have also included three subtests from the DysTest series which is used for the assessment of specific learning disorders in university students. The first subtest chosen was aimed at the perception of familiar phonemes (DysTest 3). The participant had to 1) segment heard pseudowordsinto phonemes, then 2) blend pseudowords, and 3) repeat the words backwards. The other task (DysTest 10) included reading pseudowords. Text Latyš is used for this purpose in the DysTest battery. The results of this test can prove to be interesting when compared with the functional data acquired when reading pseudowords. The last test focused on phonological elision. In this part, a participant is asked to manipulate with phonemes in the series of heard words (e.g. he/she should omit the second phoneme). The subtests taken from DysTest may provide an approximate comparison of the groups of participants with dyslexia and without it. In addition, they can provide a comparison of the functional data with the results of the tests used in clinical practice.

The results of the above mentioned tests were recorded and further processed by MANOVA in IBM SPSS Statistics 23 programme (IBM Corp., 2015).

## 3 Results

The Table 1 describes the average scores and standard deviation together with the results of statistical comparison of the groups in all the tests.

**Table 1:** *Profiles of the results of the participants with and without dyslexia in a selection observed*

| Tests | Group with dyslexia (N = 14) | Control group (N = 13) | F [1,27] | p |
|---|---|---|---|---|
| Adult reading history questionnaire (score) | 24,69 (7,49) | 56,42 (4,73) | 175,67 | 0,001 |
| Digit span (score) | 15,64 (3,27) | 16,92 (3,75) | 0,90 | 0,353 |
| Attention test (score) | 103,07 (6,27) | 104,00 (6,52) | 0,14 | 0,709 |
| RAN (seconds) | 168,91 (23,63) | 131,95 (17,05) | 21,42 | 0,001 |
| TIP (score) | 26,07 (1,94) | 25,00 (2,65) | 1,46 | 0,239 |
| DysTest 3 (score) | 28,43 (4,03) | 26,07 (1,94) | 5,86 | 0,023 |
| DysTest 10 (score) | 1,72 (0,46) | 0,96 (0,22) | 28,33 | 0,001 |
| DysTest 12 (score) | 27,36 (5,60) | 28,92 (4,11) | 0,68 | 0,418 |

The results of the tests with a significant difference will be further demonstrated in charts. These are namely ARHQ, RAN test and two subtests from DysTest series. Box plots which show the average values, upper and lower quartile and variance of standard deviation were chosen for graphic presentation of the results. There is also a significant difference of the two groups represented by „p" value and grouped by the following symbols: „*" if $p < 0.05$, „**" if $p < 0.01$, „***" if $p < 0.001$.

Regarding the Adult reading history questionnaire (ARHQ), there was a significant difference found between the groups, i.e. there is a noticeably higher possibility of reading difficulties in the group with diagnosed dyslexia in comparison with the control group. Such results indicate a high assessment value of this self-report screening tool for adults as well as a significant impact of dyslexia on reading success of so called *„high-achieving adult dyslexics"* (Cavali et al., 2017). The result is graphically demonstrated in the chart (Figure 1).

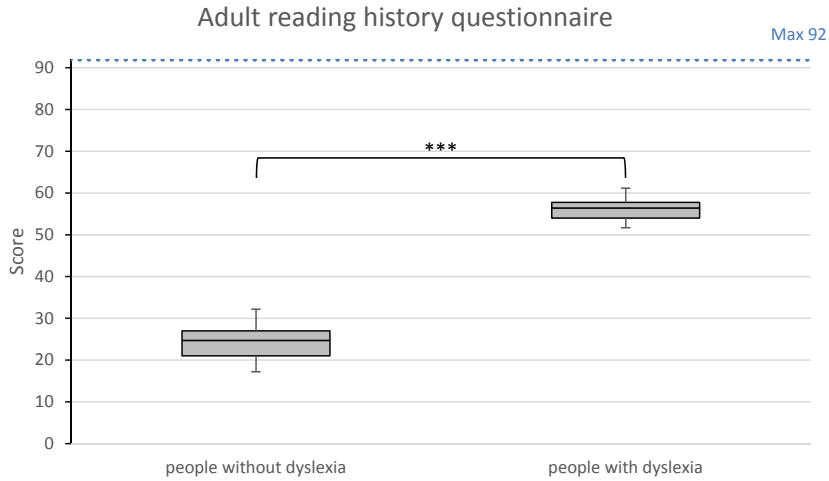


**Figure 1:** *Comparison of the results of two groups observed in ARHQ (the lower the overall score, the lesser the probability of reading difficulties).*

Another statistically significant difference was found in the score of the Rapid automatized naming. This difference was shown in individual subtests as well as in the overall evaluation. In general, the participants with dyslexia needed more time for pursuing the task in comparison with the participants without dyslexia, which is an indication of slower lexical access in the group with the disorder. Overall results are demonstrated in Figure 2.

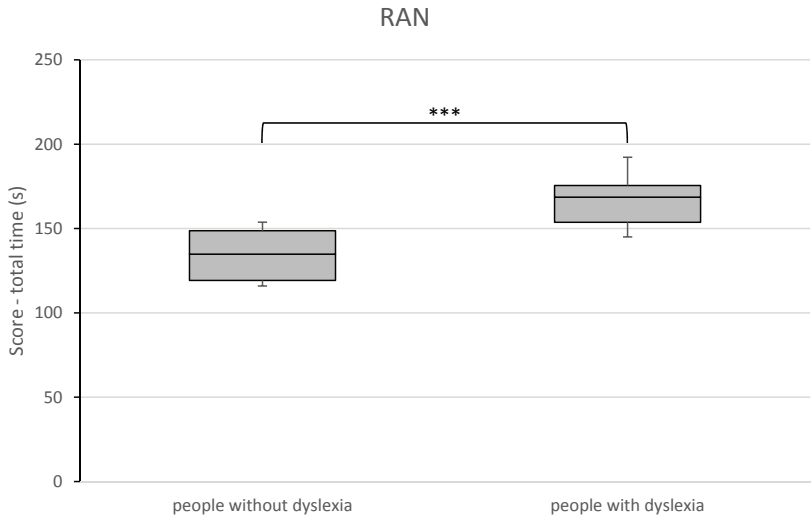


**Figure 2:** *Comparison of the results of two groups observed in the rapid automatized naming test (RAN). The chart shows the overall score in all four subtests (colour, object, digit and letter naming).*

Another statistically significant difference was found in the subtest aimed at the perception of familiar phonemes. This result shows that the participants with dyslexia experienced more difficulties when dealing with the correct blending and segmenting of the words heard. This difference may be caused by possible phonological reading difficulties. The results of the subtest are demonstrated in the following chart (Figure 3).

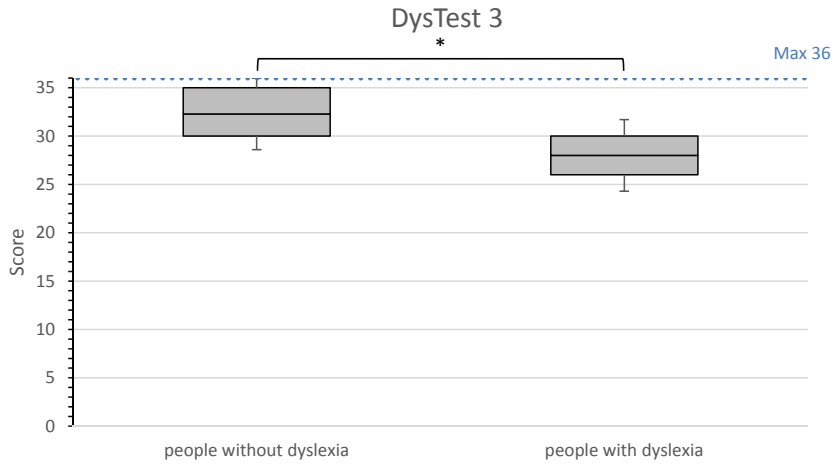


**Figure 3:** *Comparison of the results of two groups observed in the perception of familiar phonemes (DysTest).*

Last significant difference was reported in the second out of three selected sub-tests of DysTest which dealt with reading pseudowords. This result indicates that the people with dyslexia made more mistakes when reading the Latyš text, which was composed of pseudowords, and their reading speed was lower than in the control group.

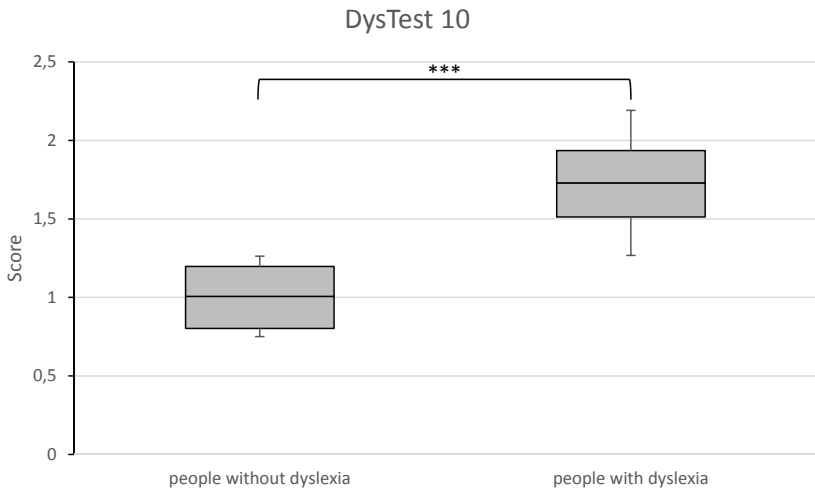


**Figure 4:** *Comparison of the results of two groups observed in the reading of pseudowords test (DysTest). Higher overall score is a sign of worse efficiency (more mistakes and lower reading speed).*

## 4 Discussion

The paper introduced a series of neuropsychological tests focused on dyslexia in adulthood with the purpose of acquiring approximate profiles of the participants and their comparison between the groups with and without dyslexia. The profiles and the outputs obtained provide a foundation for processing of further data acquired – namely the data acquired by magnetic resonance and eye tracking.

Regarding the statistical analysis of selected neuropsychological tests, it was proven that the two groups were selected by standardized criteria. It means that they vary in their performance in reading, phonological awareness and lexical access abilities and they do not vary in the level of intelligence, attention, or working memory. There were certain features of specific reading disorder in adulthood found in the target group, even though the research focused on a relatively distinctive group of university students or alumni – so called *„high-achieving adult dyslexics"* (Cavalli et al., 2017).

The only exception from the anticipated results in this part of the research is one test aimed at the level of reading abilities, namely subtest no. 12 from DysTest. In

subtest no. 12 from DysTest (which examines the level of phonological competence), there were no statistically significant differences found when comparing the performance of both groups ($F [1,27] = 0,677$; $p = 0,418$). However, the results of this subtest were supposed to show the signs of reading disorder. We assume that this unexpected result could have been caused, among others by low quality of acoustic conditions in relation to the audio recording containing pseudowords which was used during the test. Moreover, it is necessary to consider that the subtest takes into account incorrectness but not the time which was needed to pursue the tasks. Such time can be noticeably longer for people with dyslexia due to the compensatory mechanisms, which they use (e.g. visualization which facilitates phoneme processing). Another reason for such results could be a relatively high complexity of this type of the task for people without dyslexia (in comparison with dyslexic people who could be used to such type of testing due to the previous repetitive testing in counselling centres). On the other hand, relatively successful performance of the people with dyslexia could have also been caused by previous practice of the skills under discussion and by acquired use of compensatory strategies (taking into account that all the dyslexic participants were university students or alumni, we may assume that their results would be generally better than those made by all dyslexic people in the population).

There were no significant differences found in the level of attention, working memory or intellectual abilities, which only proves that the differences observed in other tests (e.g. fMRI and eye tracking, which we used) can most likely be caused by the specific reading disorder.

In the process of evaluating the results, all limits of the research which could have had an impact on the results need to be considered. When taking into account the results of the psychological tests, setting and external conditions could be the case. The tests were administered by two people, and therefore, the instructions could not have always been precisely the same (the speed of speaking, the administrator's mood, etc.) despite the preceding trials. These factors should not influence the understanding of instructions since it had been verified by a short training session before most of the tests. Nevertheless, these factors could have had an impact on the participant's mental state. Similar impact could have been caused by time factors (the tests taken in the morning vs. the tests taken in the afternoon), fatigue of the participant, etc. The results of neuropsychological tests could have been influenced, to a certain degree, by the settings where the tests were administrated (acoustics of the room, etc. – the neuropsychological tests were usually taken in the same room, however, due to insufficient capacity and time limits of the volunteers, some of the tests were administered in other rooms. Even in such cases, there were demands for quiet and calm setting). Another considerable limit was a low number of respondents.

From the results mentioned above, we can deduce that the groups under the research differ in reading of pseudowords (as one can see in DysTest 10, in which the

participant is required to read the test consisting of pseudowords). For this reason, it would be purposeful to outline the focus of other parts of the research, in which fMRI measuring was used as there were apparent differences between the groups found in reading of words and pseudowords. While the neuropsychological tests show the difference in the performance of reading abilities (speed of reading and making errors), the data acquired in fMRI indicate the core of this difference – the brain regions which are activated more/less when compared with activation the other group.

One of the tasks in fMRI test was quiet reading presented on a screen. Stimuli which include words and pseudowords had been designed for such purpose. The words and pseudowords had been chosen and made up according to their length, frequency and orthographicsimilarity. The source of appropriate Czech words was the Czech national corpus SYN2015 (Filozofická fakulta Univerzity Karlovy, 2015). The words were selected with the help of our own script in MS Excel and Wolfram Mathematica programme. The pseudowords were checked by a linguist.

As the fMRI data are not objective of this report, only the preliminary results are presented below as complementary for the psychologicaltesting (for details see Jirásková, 2019). When comparing brain activation during word reading, participants with dyslexia,compared to normal readers, had more prominent activation in inferior frontal gyrus of the left hemisphere, intraparietal sulcus and fusiform gyrus (so called Visual Word Form Area).

During pseudowords reading, participants with dyslexia, compared to normal readers showed activation in lateral occipital cortex, that can indicate higher dependence on visual processing. These regions are involved in brain system frequently reported in studies on reading and written language processing. This pattern is in accord with other studies and shows higher demand on brain processing when reading (Maisog, 2008). Differently from other studies, no compensatory activation was found in right hemisphere (Pollack et al., 2015). Specific activation pattern of the dyslexic group in the preliminary results is coherent with the neuropsychological profile described above and suggests that even highly functional adult university students / university alumni dealing with written language continue to produce behavioural and neurofunctional specifics.

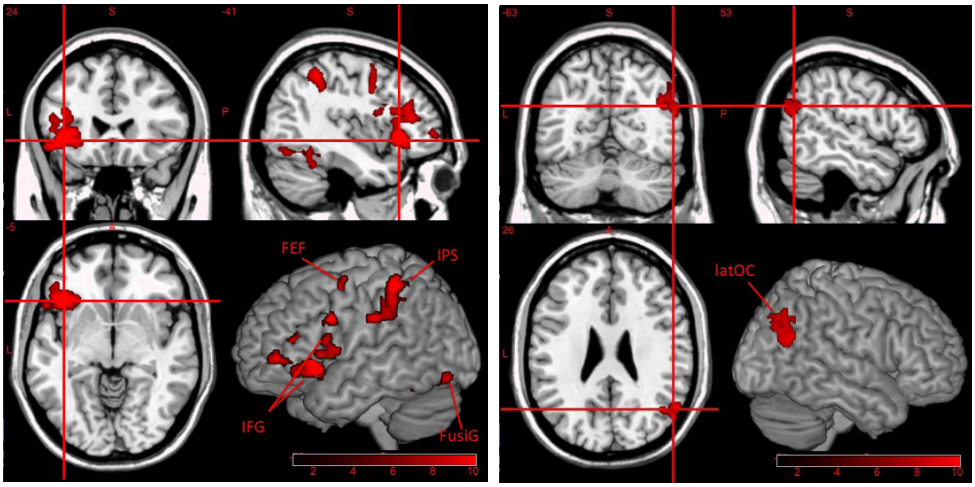


**Figure 5:** *Regions activated by dyslexic participants when compared to normal readers. On the right activation related to reading words compared to pseudowords is depicted; on the left reading pseudowords compared to words can be seen. The pictures were taken with permission from Jirásková, 2019.*

We are now seeking to involve more participants in both groups, which would contribute to a higher accuracy and validity of the gained results. The current number of participants is, to a certain degree, influenced by the criteria for participation in the research, which arise from the nature of technical devices used (fMRI and eye tracking – the limiting factors were e.g. more prominent eye disabilities, use of contact lenses, existence of metal parts in bodies, claustrophobia, or pregnancy). Regarding the prospective follow-ups of the research, we are planning to compare the results of both groups with the available data from the Brazilian research (see Lukášová, 2018).

## 5 Conclusion

Neuropsychological profiles of the participants. A series of psychological assessment tools was implemented in order to conduct the research. The results presented above refer to differences in some specific functions as well as to subjective perception of the disorder among participant of the research, taking into account the fact that the participants are adults who have studied at university. In combination with the data from fMRI, the results of the tests can reveal important connections in the scientific field of specific reading disorder. Taking into consideration the comparison of the result with the parallel research in Brazil, we can also observe the specific features of dyslexia in the context of Czech language environment. The collection of data is

still in progress due to insufficient target number or participants. Therefore, the data are to be further developed and supplied.

We have presented the first, testing part of the ongoing research, whose purpose was to obtain approximate


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