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Verbal and nonverbal sequence learning, consolidation and transfer ability: Comparison between readers with developmental dyslexia to normal readers

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Abstract

In the research literature there is a consensus about dyslexia originating from a neurological disorder. However, there is a disagreement with regard to the biological or cognitive factors that underlie dyslexia. There are 3 main theories in the literature that try to understand these processes and reveal the main causes of dyslexia: (a) **The Phonological Deficit Hypothesis** – which claims that readers with dyslexia have a difficulty with direct retrieval of phonemic language units from the long term declarative memory and with making manipulations on these units. This theory is the dominant one and receives broad support from researches in the field of dyslexia. (b) **The Magnocellular Deficit Theory** – which claims that dyslexic readers' reading problems are due to improper functioning of the magnocellular routes related to the auditory and visual systems. (c) **The Automaticity Deficit Hypothesis** – which claims that dyslexic readers fail in the process of novel information automaticity, and therefore have difficulties with automatic skills, such as reading, due to cerebral damage in areas related to the procedural learning system, with the primary inflicted area being the cerebellum.

The current study's main objective was to examine the automaticity hypothesis as the basic main cause of reading problems among dyslexic readers. In order to examine it, the current study applied a conventional paradigm of testing automatic learning of skills – the Serial Reaction Time (SRT) task. In this task, the participants are requested to respond as quickly as possible to a visual stimulus presented in one out of 4 possible locations on a computer screen. Without the participant's knowledge, the stimuli are presented according to a specific preset order that repeats itself several times. Reduction in reaction time during the learning is interpreted as reflecting learning. In order to make sure that the improvement of performance is due to learning the repeating sequence and not due to a general improvement in the task performance, in the next stage the participants are presented with a random sequence of stimuli or with a different sequence. When these stimuli are presented an increase in reaction

times is shown, reflecting the learning of the sequence practiced in previous stages.

Additional researches indicate that time by itself also plays an important role in automatic skills acquisition. The process of skills acquisition starts as of the first exposure, and in order to achieve better performance and even automaticity consolidation processes are in need. These processes are in fact about making new knowledge entering the memory less sensitive and prone to disturbances, thereby automatizing the skill and eliminating the need for the person's active control. Consolidation processes take a certain amount of time - hours to days.

A fundamental limitation of the researches that examined the automaticity process is that they overlooked learning and memory processes that appear after the initial performance of the task, after sleeping and with time – the consolidation processes. The current research adds to prior researches the examination of consolidation processes by dividing the task to two parts, with the second part being administered a day after the first part.

In most prior researches that focused on procedural learning, the nature of the displayed stimulus wasn't taken into account. Several studies that examined procedural learning of lingual nature came up with contradicting findings. Some have found difficulties in procedural learning of lingual nature and same have not. Therefore, the current study made another comparison between verbal and non-verbal contents in order to examine whether the content of the stimulus (verbal vs. non-verbal) had an influence on learning.

Finally, the current study also tried to test the transference ability among dyslexic participants – the ability to transfer knowledge from one task to another. The accepted way to test this issue is to train the person in one task and then test the level of performance in another task with similar components. If the level of performance is the same as on the first task and better than the level of performance without preliminary training on the first task, it can be concluded that knowledge transference has taken place. If dyslexic readers will indeed exhibit difficulties in automatic learning, it makes sense that they will exhibit difficulties also

with learning transference. Being that when there is a difficulty in automaticity of the learning, the performance still isn't efficient and quick and the person still has to put resources in learning, thus lowering the ability of learning transference.

Taking all of the above into account, the current study's hypotheses were that: (a) Dyslexic readers will have difficulties automatizing skills in comparison to normal readers their age but not in comparison to reading age group. (b) The content of the stimulus will have an effect on reading, mainly among dyslexic readers who will have more difficulties with a verbal stimulus, due to language difficulties. (c) All of the experiment groups will exhibit improvement after consolidation processes, with no significant difference between groups. (d) Dyslexic readers will exhibit difficulties with learning transference in comparison to normal readers their age but not in comparison to reading age group.

The current study was conducted in elementary schools in northern Israel. Seventy two students from fourth-graders to seventh-graders, ages 9-13, participated. The participants were divided to 3 groups: 24 participants were sixth-graders and seventh-graders dyslexic students, 24 participants served as an age control group (sixth-graders) and 24 participants served as a reading level control group (fourth-graders). All of the participants were given screening tests: accuracy and fluency (Schiff and kahta, 2016), in order to make sure that the normal readers actually read in the average level expected from their age group, and that the dyslexic readers' reading level is at least 2 standard deviations lower than expected. In addition, sub-tests from the Hebrew version of the Wechsler R95 intelligence test were conducted. These tests were designated to isolate the influence of the intelligence factor on the participants' level of performance and make sure that intelligence levels of dyslexic participants and control groups are within the expected average range in their age groups. Also, tests examining the ability of

sustained attention: a test that examines tracing letters and digits (Trail Making Test – TMT) and a test that examines deletion of digits (Number Cancelling Test), in order to rule out attention deficit disorders among the participants.

For hypotheses testing, bivariate repeated measures ANOVAs between subjects were conducted: by group (age control, reading level control, dyslexic readers), experiment type (verbal/non-verbal) and a within-subjects variable- block (number of blocks for comparison).

The hypothesis about dyslexic readers having difficulties with procedural learning – in automatizing skills, was confirmed. Results have shown that dyslexic readers did exhibit a process of procedural learning when the presented stimulus was non-verbal, but their reaction times were slower than that of the age control groups throughout the learning blocks. And as predicted, no difference was found between dyslexic readers and reading age group. Meaning, dyslexic readers have performed in accordance to their reading age, their procedural learning was in accordance with their reading level. In addition, the control groups show learning in both two stimuli (verbal/non verbal) whereas dyslexic readers didn't show any learning process when the presented stimulus was verbal. These findings also confirm the hypothesis about the content of the stimulus having an influence on learning, mainly among dyslexic readers with the verbal stimulus, that their reaction time for the verbal stimulus was not improved with the progress of the experiment. Generally speaking, reaction times for the non-verbal stimulus were quicker than reaction times for the verbal stimulus. In other words, the mere fact that the stimulus involves lingual material somewhat inhibits the learning process, since the participants need to put extra resources in lingual material.

Second of all, the hypothesis that no difference will be found between different groups with regard to consolidation processes was confirmed. Both the control groups

and the dyslexic readers showed improvement in reaction times in the SRT task after a night sleep in both two stimuli. Third of all, the hypothesis that reaction times in the transference block will be longer among dyslexic readers in comparison to normal readers their age was confirmed. Overall, reaction times were slower and accuracy level was lower in the transference block (the other, different sequence) than I the preceding block. This implies that the learning wasn't transferred to the other sequence. Also, in the transference block, dyslexic readers' reaction times were slower than the age control group's reaction times. And as predicted, no difference was found between dyslexic readers and reading age group. The meaning is that the age control group had an easier time adjusting to a different sequence, while dyslexic readers had a harder time doing so. They performed in accordance with their reading age, their transference ability was in accordance with their reading level.

The content of the stimulus also had an influence on the transference block. Here too, like along the results, reaction times in the transference block were shorter for a non-verbal stimulus. Moreover, only the dyslexic readers group has shown a change (a prolongation) in reaction times only when the stimulus was non-verbal, because of the fact that among dyslexic readers there was no learning at all when the stimulus was verbal, thereby showing no difference between the transference block and the block preceding it.

In conclusion, the current study substantially strengthens the deficit hypothesis theory which claims that dyslexic readers fail to automatize new information and thus have difficulties with automatic skills, such as reading. These difficulties were intensified when the presented stimulus contained a lingual content, where no learning was shown. In addition, only following more intensive learning (6 blocks as opposed to 3 blocks in prior researches) was there evident learning among dyslexic readers. Meaning, dyslexic

readers require much more practice in order to achieve a learning process, even for non-verbal study materials.

Additionally, this study gave further proof to the fact that the same consolidation processes take place in night sleep of dyslexic readers. However, the study found difficulties in the learning transference ability among dyslexic readers. Meaning, there is a difficulty in transferring learned information to a different, similar task. This needs to be considered with regard to learning strategies and the way of teaching materials to dyslexic students.