The Effect of Trans-cranial Direct Current Stimulation (tDCS) on Auditory Verbal Learning and Reading Comprehension of Adults with Learning Disability

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Abstract

Learning disabilities inhibit the performance of 10% of the population due to their enormous impact on the ability to acquire written language skills. Specific difficulty related to written language acquisition that seem to be caused by neurological impairments and not by environmental, educational, or sensorial deprivation is known as Specific Learning Disability (American Psychiatric Association, 2013). Adults with learning disabilities may still struggle with technical reading, however of all reading skills, reading comprehension is the most crucial. Reading comprehension is imperative for acquiring an education and a profession, and for functioning effectively in society. Auditory memory plays a very important role in reading comprehension processes. Many people with learning disabilities struggle with auditory memory, as shown by the Rey Auditory Verbal Learning Test (RAVLT).

Most of the treatment used today for learning disabilities is based on remedial teaching. This study joins the growing trend of electro-modulatory interventions in brain activity, based on the hypothesis that stimulation of certain regions of the brain can improve cognitive function. The research presented here uses transcranial direct current stimulation (tDCS), and describes the potential effectiveness of one-time and continuous intervention with learning disabled adults, both for auditory learning and reading comprehension. Stimulation was applied to the dorsolateral prefrontal cortex (DLPFC), which is associated with both of these functions.

This study therefore assesses the impact of DLPFC stimulation on (1) auditory learning in adults with learning disabilities and with normal reading skills; (2) reading comprehension in adults with learning disabilities and normal reading skills; (3) reading comprehension and auditory learning in adults with learning disabilities as a result of continuous stimulation.

Four experiments were conducted with 111 participants, of whom 71 had learning disabilities and 40 had normal reading skills. The first experiment tested the impact of DLPFC stimulation on the reading comprehension skills of adults with learning disabilities (41 participants) and with normal reading skills (40 participants). Mixed design analysis was used for this study, with two between-subject variables – Group (specific reading learning disability vs. normal readers), and Type of Stimulation (active, sham); and one within-subject variable – Time (before and after

stimulation). The participants answered reading comprehension questions before and after stimulation.

The second experiment tested the impact of DLPFC stimulation on auditory learning when short-term stimulation is applied during the learning stage. Mixed design analysis was used for this experiment, with two between-subject variables – Group (specific reading learning disability vs. normal readers), and Type of Stimulation (active, sham), and one within-subject variable – Time (before and after stimulation). The participants completed an RAVLT auditory learning task before and after stimulation. Approximately one-half of the participants from the first experiment (21 with learning disabilities and 21 with normal reading skills) participated in the second experiment.

The third experiment tested the impact of stimulation on auditory learning when stimulation was applied during delays. A mixed design analysis was used, with two between-subject variables – Group (specific reading learning disability vs. normal readers), and Type of Stimulation (active, sham), and one within-subject variable – Time (before and after stimulation). The participants completed an RAVLT auditory learning task before and after stimulation. The second half of the participants in the first experiment participated in this experiment.

The fourth experiment tested the impact of continuous stimulation on reading comprehension and auditory learning in adults with learning disabilities. Mixed design analysis was used, with one between-subject variable – Type of Stimulation (active, sham), and one within-subject variable – Time (before and after stimulation). The participants completed an RAVLT auditory learning task and a reading comprehension test before and after stimulation.

Hypotheses:

1. Anodal stimulation in the DLPFC region will improve reading comprehension skills primarily among adults with a specific learning disability.
2. Anodal stimulation in the DLPFC region will improve **overall auditory learning** and **delayed recall** in both groups (with and without learning disabilities), when stimulation occurs during learning.

3. Anodal stimulation in the DLPFC region will improve **delayed recall** in both groups (with and without learning disabilities), when stimulation occurs during the delay, before retrieval.
4. Anodal stimulation in the DLPFC region will reduce **loss of information** in both groups (with and without learning disabilities), when stimulation occurs during delays, before retrieval.
5. Continuous anodal stimulation in the DLPFC region will improve reading comprehension among adults with a specific learning disability.
6. Continuous anodal stimulation in the DLPFC region will improve **overall auditory learning** in adults with a specific learning disability.
7. Continuous anodal stimulation in the DLPFC region will improve **delayed recall** and thus reduce **loss of information** in adults with a specific learning disability.

Findings:

a. Hypothesis no. 1 was fully confirmed, as adults with learning disabilities improved their reading comprehension skills following active anodal stimulation, compared to those that received sham stimulation. The improvement in reading comprehension in the learning disabilities group was greater than the significant improvement observed for adults with normal reading skills.
b. Hypothesis no. 2 was partially confirmed. Auditory learning showed more significant improvement in adults who received active stimulation during the learning stage than in adults that received sham stimulation. No significant difference in auditory learning was found for adults with normal reading skills between those who received active vs. sham stimulation. In addition, delayed recall improved as a result of active stimulation compared to sham stimulation. However, active stimulation was not shown to have a differential impact on either of the groups (learning disabilities, normal readers).
c. Hypothesis no. 3 was fully confirmed. There was a significant improvement in delayed recall among adults with learning disabilities and with normal reading skills who received active stimulation during **delays** compared to adults with learning disabilities who received

sham stimulation. The improvement was significantly greater for adults with learning disabilities than for those with normal reading skills.

d. Hypothesis 4 was fully confirmed. Loss of information was lower in adults with and without learning disabilities who received active stimulation during **delays** compared to adult with learning disabilities who received sham stimulation.
e. Hypothesis 5 was fully confirmed. Adults with learning disabilities who received continuous treatment using active stimulation improved their reading comprehension skills compared to adults with learning disabilities who received sham stimulation.
f. Hypothesis 6 was not confirmed. Total learning did not improve for adults with learning disabilities who received continuous treatment with active stimulation compared to those who received sham stimulation.
g. Hypothesis 7 was fully confirmed. There was a significant improvement in delayed recall for adults with learning disabilities who received continuous treatment with active stimulation compared to those who received sham stimulation. There was also a significant reduction in loss of information among adults with learning disabilities who received continuous treatment with active stimulation compared to those who received sham stimulation.

Conclusions:

1. Active DLPFC stimulation improves reading comprehension and auditory learning in adults with learning disabilities and in those with normal reading skills.
2. The impact of DLPFC stimulation on delayed recall is the most significant.
3. Continuous stimulation improves reading comprehension and retrieval in adults with learning disabilities.

In summary, the importance of this study is twofold. From the theoretical perspective, this research helps develop a better understanding of the role of the DLPFC in auditory learning and reading comprehension. It suggests that the DLPFC is associated more with retrieval processes than with coding processes. The study also reinforces the hypothesis of memory deficiency in adults with learning disabilities. On the practical level, this study offers new opportunities for proposing treatment protocols for adults with learning disabilities who suffer from memory and reading comprehension deficiencies. It also suggests that continuous tDCS treatment may be a successful strategy for adults with auditory memory impairments.