

Voice Selector Study – an assistive technology for students with ADHD: a pilot study

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Abstract

Attention deficit hyperactivity disorder (ADHD) is a chronic neurodevelopmental disorder. Its' inattention's symptoms include distractibility and short attention span, debilitating the learning process in class. "Voice Selector Study" is a directional microphone developed to improve speech intelligibility in noisy backgrounds by selecting desired listening direction and attenuating all other directions. The aim of this pilot study was to estimate its efficacy for students with ADHD. 31 adolescents aged 14-18 years with ADHD used "Voice Selector Study" for five days at school and filled daily questionnaires - Listening Inventory for Education-Revised (LIFE-R) and Student Experience Questionnaire (SEQ) and regarding their functioning in class. The results showed significant improvements in most of the items, specifically highly significant improvements in items focused on distractibility and attention span. Results indicate a probable efficacy of the Voice Selector Study as an additive treatment for ADHD.

Introduction

Attention deficit Hyperactivity Disorder (ADHD) is a chronic neurodevelopmental disorder characterized by inattention, hyperactivity, and impulsivity, as well as executive dysfunctions. Individuals who suffer from ADHD tend to have difficulties in sustaining attention and are easily distracted, which frequently causes significant difficulties in performing tasks requiring sustained attention, such as sustained reading or participation in a classroom.¹ In children, the difficulties described

above are amplified by the classroom environment, which is often noisy, thus negatively affects their speech recognition performance.²

Attending to and understanding speech requires mental effort. this effort is referred to as "Listening effort" and it involves deliberate allocation of mental resources to overcome obstacles during a listening task.^{3,4} Recently, studies found that listening effort is increased among those with ADHD and that young adults with ADHD had more difficulty than controls when listening to speech, both in noise and in quiet.^{5,6} Among students, who need to continuously process great volumes of auditory and visual information, much more effort may be expended by those with ADHD than those without it, to reach the same result. This is associated with distraction, poor retention of information and fatigue.

Difficulties of students with ADHD are further emphasized in a school setting, where the teacher's voice is often presented in unfavorable signal to noise ratio (SNR, i.e., how loud the signal is compared to the noise). Previous studies have shown that a favorable signal to noise ratio in the classroom facilitates attention to tasks as well as improving response times in children. When the teachers' voice becomes clearer, children exhibit longer focus time and greater concentration on relevant sound stimuli and ignore competitive stimuli.⁷ This study assessed the effect of improving SNR in a population of students with ADHD.

Nuance Hearing has developed a device called Voice Selector Study that enables focused listening. It consists of a table microphone array and advanced beamforming algorithms designed

to enhance sound source from one direction, while reducing sounds coming from other directions. The user can choose the preferred listening direction (or Voice Selector Study focuses automatically on the teacher) and auditory stimuli from other directions are toned down by 15dB, thus improving SNR. This may help the user to better focus on and understand the desired speaker, i.e., the teacher.

The aim of this pilot study was to examine whether Voice Selector Study would improve the ability of adolescents with ADHD in the classroom to avoid auditory distractions and to improve their attention to the target stimulus (the teacher) while ignoring other stimuli.

Methods

Participants: Participants were 31 male adolescents aged 14-18 ($M = 15$, $SD = 1.1$) diagnosed with ADHD according to DSM-V criteria. Their diagnoses were confirmed by the primary investigator, Prof. Iris Manor, a senior child and adolescent psychiatrist. Patients with moderate to severe comorbid psychiatric disorders, neurological disorders, or any other significant chronic illness were excluded. Treated participants were asked to keep their usual medications and any other treatment routine. The study was approved by the IRB committee of Geha MHC. Overall, 28 participants were included in data analyses. Two participants dropped from the study because they could not handle the device's technical instructions' despite having help. One participant did not get permission from his school to use the device at class.

Measures: Listening inventory for education (revised). LIFE-R is a questionnaire typically used to evaluate classroom listening situations. It consists of 10 statements describing typical listening situations in school on a five-point Likert scale (0 = always difficult, 2 = mostly

difficult, 5 = sometimes difficult, 7 = mostly easy and 10 = always easy). In total 100 points (no challenge) could be obtained (range 0-100). This questionnaire has been used in previous studies to evaluate learning difficulties or benefits of an FM (frequency modulation) systems designed to improve SNR for students with hearing loss or ADHD. It has demonstrated good internal consistency before ($\alpha = 0.86$) and after ($\alpha=0.88$) intervention.⁸

Student experience questionnaire.

Adapted from Duarte Da Cruz and colleagues (2016), the SEQ includes 9 items, which are rated by students on a four-point Likert scale ranging from 1 (never) to 4 (always). Five items (1,2,3,7,8) depict negative experiences, and scores on these items are re-ordered, so that a higher value indicates a more positive experience. The total score is calculated by averaging responses in 9 items. The scale has demonstrated good internal consistency before ($\alpha = 0.76$) and after ($\alpha=0.77$) intervention.⁹

ADHD rating scale. The ADHD-RS is a rating scale which aims to assess current ADHD symptoms. The parent ADHD-RS contains 18 items, which are rated by child's parents on a four-point Likert scale ranging from 0 (never) to 3 (very often). The total score was calculated by summing up all rated items (score range 0-54). It has demonstrated good internal consistency before ($\alpha = 0.87$) and after ($\alpha=0.89$) intervention.¹⁰

Procedure

After the parents and the adolescent signed a consent form, the participants were given a letter addressed to their school headmaster with information about the study, the part of the participant in it, and a request to permit him to use the device at school. They filled out the questionnaires LIFE-R and SEQ regarding their usual performance in class. Parents were instructed to fill the ADHD-RS. Participants were

then instructed how to use the device and had an adaptation period of two days. The intervention was meant to last five consecutive days, during which participants were able to use the device at school (for as many hours as desired), but because of the outbreak of Covid-19, this rule could not always be kept, and some had to use the device not on consecutive days. Each day the students used the device, they filled out on-line LIFE-R and the SEQ regarding their performance with the device on that day.

At the end of the intervention, participants returned the device, and their parents re-filled the ADHD-RS, regarding the period of the intervention. The participants were asked how they perceived their performance during the study period though no rating scale nor side effects questionnaire was used. After results were collected, the participants' names were coded, and responses were analyzed.

Nuance hearing ltd. company had no access to any identifying detail of the participants.

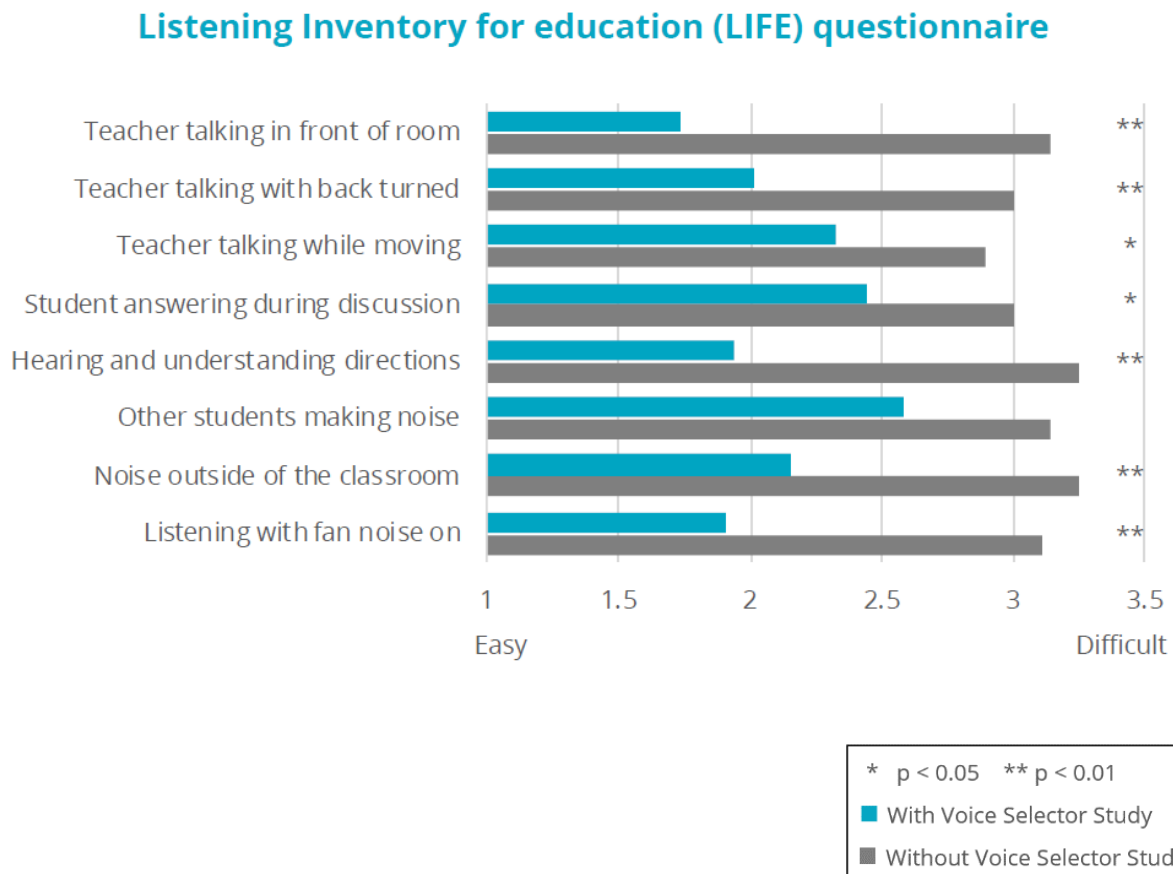
Statistical analysis

Paired t-test analysis was used to compare mean differences in LIFE-R, SEQ and ADHD-RS results before and after intervention. A two-tailed P value lower than 0.05 was considered statistically significant.

Results

Listening inventory for education. As presented in Figure 1, eight out of ten items demonstrated significant change, seven of them highly significant change ($p < 0.1$). These were items concerning the ability to avoid distraction.

Figure 1 – Averaged scores of the listening inventory for education with and without Voice Selector Study



Student experience questionnaire. As presented in Figures 2a and 2b, a highly significant difference ($p < .001$) was found in 4 items out of 9 and a significant difference ($p < .05$) was demonstrated in 2 items out of 9 pre- and post- intervention. Items with highly significant changes dealt with the improvement of the attention process including the ability to avoid distractions, the better focus, and better understand the teacher.

For visual presentation, Items were divided to two groups – those with positive statements and those with negative statements, and those are represented in figures 2a and 2b, respectively.

ADHD rating scale There was no significant change in the ADHD-RS scores that the parents filled out pre- and post- intervention.

Figure 2a – Averaged scores of the positive statements of the student experience questionnaire with and without Voice Selector Study

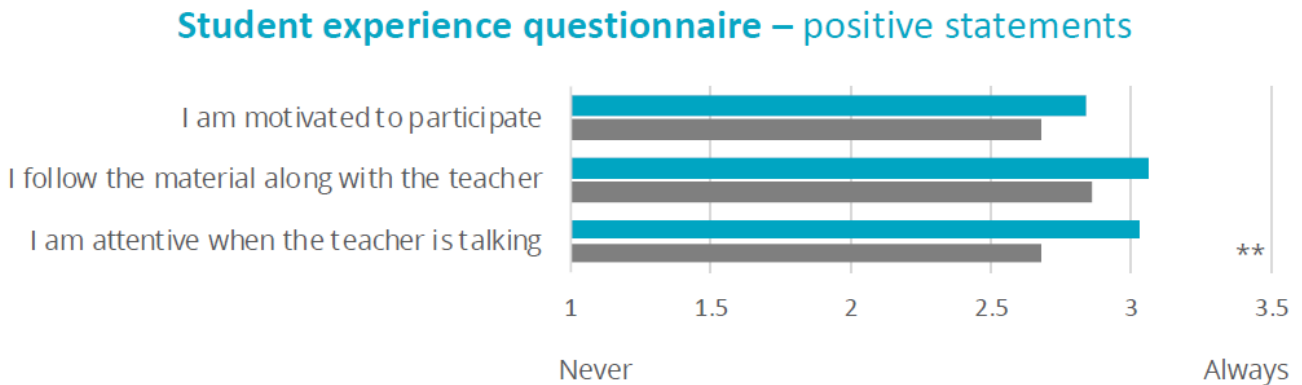
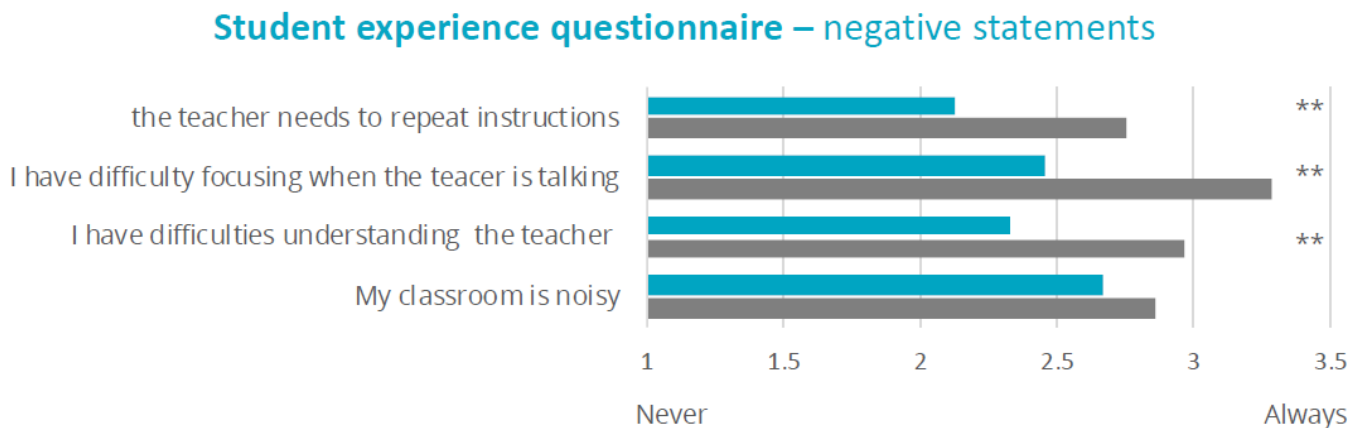


Figure 2b – Averaged scores of the positive statements of the student experience questionnaire with and without Voice Selector Study



* $p < 0.05$ ** $p < 0.01$
 ■ With Voice Selector Study
 ■ Without Voice Selector Study

All participants were asked about their experience, although without any formal questionnaire. Most of them reported satisfaction from using the device, and some asked to be connected to the company to purchase the device. As was mentioned above, two students had difficulty managing the device to the degree that they had to stop the trial. Other than that, no significant side effect was reported.

The outbreak of Covid-19 happened in the beginning of February in Israel and became a national crisis at the beginning of March. One of the results was the closing of schools. It caused a forced and an arbitrary stop at the middle of the study, some participants were stopped in the middle of their intervention period, others already signed an informed consent but could not begin. The studies at school were renewed only in May, and were not always continuous, but integrated with studies on-line. Thus, the study's demand for consecutive days was violated. Alongside the level of national tension and the Covid-19 restrictions (such as wearing a mask in class) it called for the concern that Covid -19 and its consequences had an effect on the results. However, COVID-19 showed no significant effect or interaction, neither on the LIFE-R total score, [F(1,26) = 0.11, $p = .74$; F(1,26) = 0.80, $p = .38$, respectively] nor on the SEQ total score, [F(1,26) = 1.49, $p = .23$; F(1,26) = 0.13, $p = .72$, respectively).

Discussion

This pilot study aimed to estimate the efficacy of Voice Selector Study to improve the functioning of ADHD students, as exhibited in the classroom environment. The results demonstrated highly significant improvements in specific executive dysfunctions and the deficits in the attention process. Improvement was reflected by lesser distractibility, better focus and

better understanding of the teacher. Significant improvements were found in the behavioral items, maybe as a hint of the correlation between the quality of the attention process and the behavior at class. There was no improvement in the motivation of the participants, nor in their flexibility (the possibility to quickly move their attention from one target stimulus to the next) or ability to ignore visual distractions.

LIFE-R and SEQ were found to be possible measures for ADHD specific dysfunctions in the classroom, while a standard ADHD measuring tool, the ADHD-RS, was found lacking in this aspect. This may indicate the need to use tools from other fields that were not specifically designed for ADHD and to design ADHD tools that would measure other specific executive functions.

Subjectively most of the participants reported a perception of improvement that was also reflected by their scores. Two participants could not handle the device, which calls for a better discrimination of people with ADHD who may benefit from it.

In summary, it seems that Voice Selector Study could be a promising additive tool in the treatment of ADHD. A larger, more detailed study (gender, ages, comorbidities) that would establish the efficacy of Voice Selector Study as an addition to the integrative treatment of ADHD is suggested.

Limitations

This was a pilot study, meaning that the population was small and had some restrictive demands, like age, gender, and comorbidities. It was also a short period study. For the same reason, other analyses, such as ADHD presentation, could not be done. The lack of specific tools to measure the efficacy of such a device was very apparent and the inefficacy of

the “usual” ADHD scales and questionnaires became apparent.

Disclosure

This study was funded by “Nuance Hearing”. There were no financial or other relationship between the investigators and the company.

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