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RESULTS OF THE USE OF SPPS-S[®] (STIMULATION OF POLYMODAL SENSORY PERCEPTION BY SKARŻYŃSKI) BASED ON 4009 PATIENTS WITH CENTRAL AUDITORY PROCESSING DISORDER

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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Abstract

Introduction: Central auditory processing disorder (CAPD) significantly impair auditory, cognitive, and communicative functioning. Effective rehabilitation requires comprehensive therapeutic approaches integrating multisensory stimulation and modern telemedicine solutions. This study aimed to present the Skarzynski's Polymodal Sensory Perception Stimulation (SPPS-S[®]) method and evaluate its effectiveness based on outcomes from over 4,000 patients with CAPD.

Material and methods: The analysis included 4009 patients who underwent SPPS-S[®] therapy and a control group of 30 individuals. Auditory processing abilities were assessed using the Frequency Pattern Test (FPT), Duration Pattern Test (DPT), and Dichotic Digit Test (DDT), before and after approximately 3 months of therapy. Statistical analysis was performed using the Wilcoxon signed-rank test.

Results: Statistically significant improvements were observed in all assessed auditory processing parameters following SPPS-S[®] therapy ($p < 0.05$), in both pediatric and adult populations. No significant changes were found in the control group.

Conclusions: SPPS-S[®] is an effective, safe, and versatile therapeutic method for CAPD rehabilitation, suitable for both in-clinic and home-based settings, including telemedicine-supported therapy.

Keywords: central auditory processing disorder • CAPD • SPPS-S[®]

WYNIKI STYMULACJI POLIMODALNEJ PERCEPCJI SENSORYCZNEJ METODĄ SKARŻYŃSKIEGO (SPPS-S[®]) NA PODSTAWIE WYNIKÓW PONAD 4 TYSIĘCY PACJENTÓW Z CENTRALNYMI ZABURZENIAMI PRZETWARZANIA SŁUCHOWEGO

Streszczenie

Wprowadzenie: Centralne zaburzenia przetwarzania słuchowego (CAPD) istotnie wpływają na funkcjonowanie słuchowe, poznawcze i komunikacyjne. Efektywna forma rehabilitacji wykorzystuje kompleksowe podejścia terapeutyczne, integrując stymulację wielozmysłową oraz nowoczesne rozwiązania telemedyczne. Celem niniejszej pracy było przedstawienie metody Stymulacji Polimodalnej Percepcji Sensorycznej metodą Skarżyńskiego (SPPS-S[®]) oraz ocena jej skuteczności na podstawie wyników ponad 4000 pacjentów z CAPD.

Materiał i metody: Analiza objęła wyniki ponad 4000 pacjentów poddanych terapii SPPS-S[®] oraz grupę kontrolną liczącą 30 osób. Procesy przetwarzania słuchowego oceniano za pomocą testu sekwencji częstotliwości (FPT), testu sekwencji czasu trwania (DPT) oraz rozdzielności testu liczbowego (DDT), przed terapią i po jej zakończeniu, po około trzech miesiącach. Analizę statystyczną przeprowadzono z wykorzystaniem testu rang podpisanych Wilcoxon.

Wyniki: Po terapii SPPS-S[®] zaobserwowano statystycznie istotną poprawę we wszystkich ocenianych parametrach przetwarzania słuchowego ($p < 0,05$), zarówno w populacji dzieci, jak i dorosłych. W grupie kontrolnej nie stwierdzono istotnych zmian.

Wnioski: SPPS-S[®] jest skuteczną, bezpieczną i wszechstronną metodą terapeutyczną w rehabilitacji CAPD. Może być stosowana zarówno w ośrodkach klinicznych oraz dzięki wykorzystaniu telemedycyny w warunkach domowych.

Słowa kluczowe: centralne zaburzenia przetwarzania słuchowego • CAPD • SPPS-S[®]

Key to abbreviations	
ADHD	Attention Deficit Hyperactivity Disorder
CAPD	central auditory processing disorder
DDT	Dichotic Digit Test
DPT	Duration Pattern Test
FPT	Frequency Pattern Test
LE	left ear
RE	right ear
SLI	Specific Language Impairment
SPPS-S [®]	Stimulation of Polymodal Sensory Perception by Skarżyński (Stymulacja Polimodalnej Percepcji Sensorycznej metodą Skarżyńskiego)

Introduction

Central auditory processing disorder (CAPD), according to the definition of the American Speech-Language-Hearing Association [1], is a difficulty in processing auditory information at the level of the central nervous system, despite normal structure and function of the peripheral auditory system. These processes underlie essential auditory skills, including sound localization and lateralization, sound discrimination, recognition of auditory patterns, analysis of the temporal aspects of auditory signals, and temporal integration of sounds. These difficulties, considered as a constellation of symptoms, can significantly affect an individual's daily functioning. The most commonly reported manifestations comprise: difficulty hearing in noisy environments, problems following complex verbal instructions, misperception of similar-sounding words, frequent requests for repetition, challenges in reading and writing, reduced attention span, susceptibility to distraction, and auditory hypersensitivity [2–6].

The difficulties may occur individually or co-occur in varying degrees and forms; however, all can significantly impact multiple aspects of daily life. CAPD is addressed by a wide range of specialists, including otorhinolaryngologists, audiologists, speech-language pathologists, educators, and psychologists [7–9]. The diagnosis is established by a physician, while the patient's rehabilitation, depending on individual needs, involves collaboration with a range of specialists.

Many authors have addressed the diagnosis and the effectiveness of various therapeutic interventions for patients with CAPD across various comorbid conditions [9,10]. Therapies have shown considerable effectiveness

in addressing the primary disorder, such as reducing the severity of stuttering and improving central auditory processing abilities [10]. The range of rehabilitation services offered by centers supporting this patient group is continuously expanding, and the market for therapeutic services in the field of auditory training and therapy is growing. The increasing possibilities for rehabilitation interventions are closely linked to the development of telemedicine [11–13].

During the COVID-19 pandemic, access to medical services was significantly restricted. These limitations also affected the availability of various rehabilitation interventions, including in-person auditory therapies, which constitute a primary component of support strategies for children with CAPD.

The auditory therapy used in this study, Stimulation of Polymodal Sensory Perception by Skarżyński (SPPS-S[®]), is a form of intervention originally designed to be implemented in either remote or in-person format. It has been successfully applied since 2014 in numerous locations across Poland as well as abroad. The SPPS-S[®] is the only one device on the Polish market to hold medical device compliance certification.

Aim

The aim of this study is to present the method and evaluate its effectiveness based on the outcomes of 4009 patients who have undergone SPPS-S[®] therapy.

Material and methods

SPPS-S[®]

Skarżyński's Method of Polymodal Sensory Perception Stimulation (SPPS-S[®]) is a therapy applied across various groups of disorders comorbid with CAPD. According to the literature, auditory processing difficulties affect perhaps several percent of the school-aged population; however, in children with dyslexia, problems with auditory processing may occur in over 30% of cases [6,14], and in children diagnosed with SLI or ADHD, this figure can reach up to 50% [3,15].

SPPS-S[®] is designed to perform therapy on multiple levels simultaneously. Various human senses – hearing, vision, and touch – are engaged, with the aim of integrating and coordinating them. The SPPS-S[®] approach is to supply simultaneous stimulation.

SPPS-S[®] therapy consists of three levels, but in cases of insufficient improvement, there is the possibility of continuing the stimulation. Each level of therapy lasts 4, 5, or 10 days. The therapy is composed of three components: listening to audio material processed through the device, relaxation, and multimedia and psychoeducational games conducted on a tablet.

During the listening phase, patients are exposed to the processed audio material. In the first two levels, their task is passive listening. During this time, they may engage in various manual activities, play games, assemble blocks, or participate in other activities. In the next stage, relaxation, patients listen to a narrator's voice accompanied by relaxing music while assuming a comfortable position, preferably lying down. The third stage of therapy involves multimedia and psychoeducational games. The multimedia games primarily target auditory skills such as sound intensity discrimination; sound frequency discrimination; sound duration discrimination; auditory memory; sound localization; and other related skills. The audio material used in the games is based on environmental sounds; instrumental/music sounds; and speech sounds.

An innovative aspect is the combination of auditory stimulation with psychological training. Emotions play a crucial role in communication, and disturbances in this domain constitute one aspect of CAPD. Misinterpretation in verbal communication can not only lead to misunderstandings and affect social relationships but may also significantly impact an individual's self-esteem, since communication difficulties accumulate and contribute to a sense of being misunderstood. Integrating psychological therapy with auditory function training provides a much greater potential for effectively supporting individuals struggling with auditory processing difficulties.

Qualification for the SPPS-S program and programming of therapy were performed using the SPPS-S® panel as well as disorder-specific standardized forms. This arrangement was intended to support collection of diagnostic information and therapy programming in a uniform way, one which is suitable for routine clinical practice. The SPPS® Panel is available via a dedicated website accessible only to certified therapists, where patient diagnostic data are entered in the appropriate sections. For each disorder group for which SPPS-S® therapy programs have been developed, separate data entry sheets have been prepared. These sheets include forms for entering additional disorder-specific information, such as articulation assessment (for dyslalia and delayed speech development) or phonemic hearing evaluation (for reading and writing disorders). However, for all groups, the mandatory data required to initiate SPPS-S® therapy are the results of the following tests assessing central auditory processing.

- **FPT (Frequency Pattern Test)** – a test for discriminating sequences of sounds differing in frequency. The test includes 40 random sequences, each consisting of three sequential tones, one of which differs in frequency from the others (high tone – 1122 Hz, low tone – 880 Hz), presented at an intensity of 50 dB HL. This test evaluates the ability to discriminate sound frequencies as well as short-term auditory memory. During the test, the patient's task is to report the order of tones in each sequence. The maximum score is 100% [16].
- **DPT (Duration Pattern Test)** – a test for discriminating sequences of sounds differing in duration. The test includes 40 sequences, each consisting of three tones, one of which differs in duration from the others (long tone – 500 ms, short tone – 250 ms), presented

at an intensity of 50 dB HL. This test assesses the ability to discriminate sound duration and short-term auditory memory. During the test, the patient's task is to report the order of tones in each sequence. The maximum score is 100% [17].

- **DDT (Dichotic Digit Test)** – a dichotic digit test in which the patient repeats 20 pairs of digits presented binaurally. This test evaluates the integration of information from both ears and the transfer of that information between brain hemispheres. During the test, the patient hears two pairs of digits simultaneously, different for the right and left ears. Results are reported separately for the right ear (RE) and the left ear (LE). The maximum score is 100% for the right ear and for the left [17].

SPPS-S® therapy can be conducted either in a therapeutic center or at home (in-person or remote format). The device itself, along with therapy programming and various technical solutions (e.g., inter-training interval locks, supervised access, the possibility of remote connection to the SPPS-S® set), as well as device certification, mean that the therapy can be safely and effectively conducted at home after appropriate parent/caregiver training.

The effectiveness of both formats has been demonstrated in a publication [18] comparing the outcomes of patients undergoing remote versus in-person therapy. Statistically significant therapeutic effects were observed, and the effect size (ES) parameter was above 0.8 for both therapy formats, confirming that both approaches delivered a very high therapeutic effect.

The choice of therapy format is determined by several factors. The most important is based on the patient's difficulties and capabilities – for example, group therapy may be advantageous in some cases, or, at other times, inappropriate. In some situations, the home-based format is chosen due to the family's daily schedule or the high costs associated with frequent travel to the diagnostic and rehabilitation center.

The present retrospective cohort included patients treated in both formats. The choice of format was individualized according to the patient's needs, family circumstances, and organizational factors. The present analysis pooled both formats and was not designed to compare them within this cohort.

Material

The material comprised the results of 4,402 patients: children (aged 6–18) and adults (aged 19–52). The study group consisted of 4,372 individuals, while the control group included 30 patients. The study was retrospective. In both the study and comparison groups, inclusion criteria were: normal peripheral hearing, a clinical diagnosis of CAPD with reported and clinically observed symptoms, and normal intellectual functioning. Patients in the study group underwent SPPS-S® therapy (in either a therapeutic center or remotely) whereas the control group consisted of patients who had been qualified for auditory therapy but were awaiting its initiation.

Patients in the study group were assessed before and after completion of SPPS-S® therapy, i.e., after approximately 3 months. The same two measurements (baseline and follow-up) were obtained in the control group, in which no auditory therapy or other auditory rehabilitation interventions were administered during the interval between assessments. At the end of the study period all participants in the control group began SPPS-S® therapy.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics (version 25). Descriptive statistics were calculated for quantitative variables. A nonparametric Wilcoxon test was applied to the FPT, DPT, and DDT tests to estimate changes before and after therapy. A *p*-value of < 0.05 was considered statistically significant.

Results

Results from 4,372 patients who underwent SPPS-S® therapy were obtained based on diagnostic assessments conducted before and after therapy. The tests assessing central auditory processing were FPT, DPT, DDT RE, and DDT LE. However, complete data for all tests (8 measurements: 4 before therapy and 4 afterwards) were only available for 4,009 patients. At the time of the initial assessment, the minimum patient age was 6 years and the maximum was 52 years. Mean age of children was 9.26 years (*SD* = 2.33) and mean age of adults was 32.6 years (*SD* = 10.1). All test results are expressed as percentage correct, where 100% is the maximum possible score.

Table 1 presents the results of all patients who underwent SPPS-S® therapy. The results for the subgroup of children, consisting of 3,892 individuals, are presented in **Table 2**. The results for the adult patient group, consisting of 117 individuals, are presented in **Table 3**.

Statistical analyses of patient outcomes demonstrated that SPPS-S® therapy resulted in a statistically significant improvement in all assessed auditory functions.

Table 4 presents the before and after measurements in the control group, which consisted of 30 children who did not undergo any auditory stimulation, therapy, or other rehabilitation interventions. These patients were tested twice: at the first measurement and at a second measurement approximately 3 months later. No statistically significant differences were observed between the results of the first and second measurements.

Discussion

The aim of this study was to use the SPPS-S® method and evaluate its effectiveness based on the outcomes of over 4,000 patients who underwent therapy. Statistical analyses demonstrated a statistically significant improvement in all parameters assessing central auditory processing in the study group before and after SPPS-S® therapy. The therapeutic effects were positive in both adults and children, with particularly strong improvements observed in children. Although the therapeutic outcomes in adults were also statistically significant, baseline test results prior to

therapy were higher than with children, resulting in less pronounced changes in these parameters.

These findings support the importance of early identification and timely rehabilitation planning in patients with auditory processing difficulties. According to Katz [19], CAPD is characterized by an inability to fully utilize the acoustic signal despite normal peripheral hearing. Patients function similarly to individuals with a mild degree of hearing loss, and the resulting difficulties can affect all areas of life. Therefore, prompt initiation of rehabilitation interventions is important. According to Bellis [2], therapy for patients with CAPD should be based on three main pillars: (1) auditory training targeted at specific deficits; (2) modification of the patient's functional environment; (3) compensation for and extra support of existing difficulties.

The most important area is the use of auditory training to improve impaired auditory skills. The available literature includes studies demonstrating the effectiveness of various types of auditory stimulation, such as Johansen therapy, the Safe and Sound Protocol, and the Tomatis Method [20–22]. Authors of numerous studies have demonstrated the impact of auditory training on specific brain regions [23,24], brain functioning [25,26], brain development [27,28], auditory processing [29,30], as well as on dyslexia-related disorders [31]. In one study, Rosińska et al. [10] demonstrated the effectiveness of developed auditory stimulation for patients who stutter, assessing the reduction in stuttering severity using four tests: the Cooper Questionnaire [32], the Syllable Test [33], the Dichotic Listening Test [34], and the Dichotic Digit Test [35]. Mularzuk et al. [36] demonstrated the effectiveness of the Tomatis Method in a large group of 422 first-grade students, based on an assessment of an attention test and an auditory lateralization test. Experimental and clinical studies have demonstrated that auditory training may provide measurable improvement in both behavioral test outcomes and neurophysiological parameters (such as auditory brainstem responses and cortical auditory evoked potentials). These changes can be interpreted as evidence of adaptive reorganization within the neural networks responsible for the analysis and integration of acoustic stimuli [37].

Comparing the effectiveness of available programs is not possible, mainly due to differences in diagnostic methods and qualification criteria. It should also be noted – although this is not sufficiently emphasized – that with most auditory training programs or therapies, qualifying for therapy does not equate to establishing a clinical diagnosis. Different therapeutic techniques typically have different patient inclusion criteria, usually specific to the method. Sometimes, multiple methods may be appropriate for a patient, so it is worth considering separate certification and clinically based diagnosis (as is the case with the SPPS-S®).

Given the wide range of auditory rehabilitation methods, each with their own unique features, a decision regarding appropriate therapy should be left to a certified therapist or specialists with suitable qualifications. The therapies vary in many aspects such as theoretical assumptions, inclusion and exclusion criteria, and formats (in clinic

Table 1. Effects of therapy – all respondents combined (study group) based on a Wilcoxon signed-rank test

Average results	FPT (n = 4009)			DPT (n = 4009)			DDT RE (n = 4009)			DDT LE (n = 4009)		
	M	Median	SD	M	Median	SD	M	Median	SD	M	Median	SD
Before	35.60	30.00	24.14	39.90	35.00	25.31	71.86	75.00	18.88	53.68	55.00	21.37
After	54.65	53.00	24.99	58.00	57.50	24.47	78.82	80.00	15.42	67.41	70.00	18.34
<i>p</i>	< 0.001			< 0.001			< 0.001			< 0.001		
<i>Z</i>	-48.31			-48.54			-27.83			-44.91		
<i>ES</i>	0.76			0.77			0.44			0.71		

Note: *n* – sample size; *p* – *p*-value; *Z* – Wilcoxon signed-rank test; *ES* – effect size; RE – right ear; LE – left ear.

Table 2. Effects of therapy in 3892 children in the study group

Average results	FPT (n = 3892)			DPT (n = 3892)			DDT RE (n = 3892)			DDT LE (n = 3892)		
	M	Median	SD	M	Median	SD	M	Median	SD	M	Median	SD
Before	34.16	28.00	23.81	38.48	33.00	25.24	70.73	75.00	20.01	52.58	53.00	21.75
After	53.21	50.00	25.19	56.60	55.00	24.92	77.80	80.00	16.54	66.37	67.50	18.88
<i>p</i>	< 0.001			< 0.001			< 0.001			< 0.001		
<i>Z</i>	-47.90			-47.95			-27.37			-44.27		
<i>ES</i>	0.77			0.77			0.45			0.71		

Note: *n* – sample size; *p* – *p*-value; *Z* – Wilcoxon signed-rank test; *ES* – effect size; RE – right ear; LE – left ear.

Table 3. Effects of therapy in 117 adults in the study group

Average results	FPT (n = 117)			DPT (n = 117)			DDT RE (n = 117)			DDT LE (n = 117)		
	M	Median	SD	M	Median	SD	M	Median	SD	M	Median	SD
Before	71.61	65.00	29.40	62.1	67.5	27.66	79.46	85.0	16.80	63.20	66.00	25.88
After	74.91	83.00	24.99	77.17	82.75	21.35	87.39	92.5	23.10	76.57	82.75	22.26
<i>p</i>	< 0.001			< 0.001			< 0.001			< 0.001		
<i>Z</i>	-6.31			-7.47			-5.12			-7.51		
<i>ES</i>	0.58			0.69			0.47			0.69		

Note: *n* – sample size; *p* – *p*-value; *Z* – Wilcoxon signed-rank test; *ES* – effect size; RE – right ear; LE – left ear.

Table 4. Before and after measurements in the control group (no auditory therapy administered during the observation period)

Average results	FPT (n = 30)			DPT (n = 30)			DDT RE (n = 30)			DDT LE (n = 30)		
	M	Median	SD	M	Median	SD	M	Median	SD	M	Median	SD
Before	27.00	65.00	21.50	35.17	67.5	21.24	73.33	85.0	19.41	49.83	66.00	22.97
After	26.83	83.00	23.49	33.83	82.75	30.12	70.58	92.5	19.87	45.00	82.75	22.20
<i>p</i>	0.890			0.523			0.221			0.054		
<i>Z</i>	-0.14			-0.64			-1.13			-1.92		
<i>ES</i>	0.03			0.12			0.21			0.35		

Note: *n* – sample size; *p* – *p*-value; *Z* – Wilcoxon signed-rank test; *ES* – effect size; RE – right ear; LE – left ear.

or at the patient's home, and individually or in groups). Training can also take the form of passive exercises that don't require active cooperation or active exercises that do.

This study has several limitations. First, it was retrospective, non-randomized, and non-blinded, which limits causal inference. Second, the waiting-list comparison group was small and not formally matched to the treatment cohort. Third, the cohort was heterogeneous with respect to age and comorbid conditions, and no subgroup analyses beyond children versus adults were performed. Fourth, detailed adverse-event/safety outcomes were not formally analyzed. These limitations should be considered when interpreting the findings.

In future studies, the authors plan to include long-term therapeutic effects, detailed surveys, a larger control group, and perhaps a placebo group. Future prospective studies should also include random allocation and blinded outcome assessments to strengthen the validity of the findings. The coexistence of CAPD with other diseases is also a factor that may influence the effects of therapy and needs to be taken account of in future studies.

Conclusions

This study presents the results of 4,009 patients who underwent therapy using the SPPS-S[®] method. In this large retrospective clinical cohort, SPPS-S[®] therapy was associated with a statistically significant improvement across all evaluated central auditory processing measures. These findings suggest that SPPS-S[®] may be a promising therapeutic option for patients with CAPD who are being treated either in-person or in a remote setting. However, the

observational design, lack of blinding, and small control group mean that the results should be interpreted with caution and confirmed in prospective randomized studies.

Conflict of interests

The method presented in this manuscript was originally developed by Henryk Skarzynski, whose surname forms part of the method's name. Because both Henryk Skarzynski and Piotr H. Skarzynski are co-authors of this article, this circumstance may reasonably be viewed as a potential competing interest. The authors declare that this relationship did not influence the study design, data interpretation, or conclusions.

Ethics statement

The study received approval from the Bioethics Committee KB/07/2017. Informed consent was not required due to the retrospective nature of the study.

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