Autism, Hypersensitivity and Language Ability

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Abstract. A study with 36 German participants (divided in 3 age groups: 1 gr. 7–11 years; 2 gr. 12–18 years and 3 gr. 19–50 years) was conducted to test the polyvagal theory. Our data analysis evaluated a therapeutic intervention using the so-called SSP (Safe and Sound Protocol) developed by Stephen Porges. Frequency modulated music stimulates the parasympathetic vagus nerve with an (musical) input process evaluated by the brain as social-communicatively salient (musical signals with enhanced prosodic characteristics of human voices). Thus, acoustical processes of (musical) perception become available to the brain's assessment of social signals via the neurophysiology of the ANS. This, in turn, allows for internally processed signals of social safety, resulting in a reduced sense of stress from external sensory inputs. The SSP aims to generally reduce sensoric hypersensitivity by stimulating the vagus nerve via the middle ear – and thus, to contribute to a better capacity of (down)-regulating sensoric hypersensitivity. In the current study, we demonstrated that participants with ASD showed reduced hyper-sensitivity (visual, auditory, tactile and digestive) after using the SSP. In a second data analysis, we tested the overall impact of language ability, age, self-care ability and its influence on hypersensory sensitivity in the autism spectrum. It seems that language ability in general already leads to better regulation and integration of sensory inputs via cognitive-linguistical processing in cortex areas: If a strong sensory stimulus can be assigned and evaluated linguistically, the strength of the stimulus is adjusted thereby. Conversely, different language abilities did not result in a more effective response to the SSP. Since the SSP amplifies prosodic elements of human speech in a characteristic way, the effect of reduced sensitivity to stimuli seems to be due to the autonomic response to paraverbal signals. The results are statistically analyzed using ANOVA.

Keywords: *polyvagal theory, autism, hypersensitivity, language development*.

Кючуков Хрісто, Акерманн Міхель. Аутизм, гіперчутливість і мовна здатність.

Анотація. Дослідження за участі 36 німецьких учасників (розділених на 3 вікові групи: 1 гр. 7–11 років; 2 гр. 12–18 років і 3 гр. 19–50 років) було проведено з метою перевірки полівагальної теорії. Наш аналіз даних оцінював терапевтичне втручання з використанням так званого SSP (Safe and Sound Protocol), розробленого Стівеном Поргесом. Частотно-модульована музика стимулює парасимпатичний блукаючий нерв за допомогою (музичного) вхідного процесу, який мозок оцінює як соціально-комунікативно значущий (музичні сигнали з посиленими просодичними характеристиками людських голосів). Отже, акустичні процеси (музичного) сприйняття стають доступними для оцінки мозком соціальних сигналів через нейрофізіологію АНС. Це, в свою чергу, дає змогу внутрішньо обробляти сигнали соціальної безпеки, що приводить до зменшення відчуття стресу від зовнішніх сенсорних вхідних сигналів.

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SSP спрямований на загальне зниження сенсорної гіперчутливості шляхом стимуляції блукаючого нерва через середнє вухо, відтак сприяє тенденції до зниження сенсорної гіперчутливості. У поточному дослідженні ми продемонстрували, що учасники з РАС показали зниження гіперчутливості (зорової, слухової, тактильної й травної) після використання SSP. У другому аналізі даних ми перевірили загальний вплив мовних здібностей та вплив на гіперчутливість у спектрі аутизму. Схоже, що мовна здатність загалом уже спричинює кращу регуляцію та інтеграцію сенсорних входів шляхом когнітивно-лінгвістичної обробки в ділянках кори: за умови, якщо потужний сенсорний стимул може бути сприйнято й перероблено лінгвістично, це й коригує силу цього стимулу. І навпаки, різні мовні здатності не приводять до ефективнішої реакції на SSP. Оскільки SSP характерним чином підсилює просодичні елементи людського мовлення, ефект зниження чутливості до стимулів, можливо, пов'язаний з вегетативною реакцією на паравербальні сигнали. Результати статистично оброблено за допомогою ANOVA.

Ключові слова: *полівагальна теорія, аутизм, гіперчутливість, мовний розвиток.*

Introduction

The Polyvagal Theory

Stephen Porges has pointed to the context of research from the 1960s to the 1980s in the field of biopsychology, an area then predominantly dealt with by "psychophysiology". In a study (Porges, 1995) explained that the vagus, the 10th cranial nerve, contains pathways that contribute to the regulation of the internal viscera, including the heart. Vagal efferent fibers do not originate in a common brainstem structure. The Polyvagal Theory is introduced to explain the different functions of the two primary medullary source nuclei of the vagus: the nucleus ambiguous (NA) and the dorsal motor nucleus (DMNX). Although vagal pathways from both nuclei terminate on the sinoatrial node, the author argues that the fibers originating in NA are uniquely responsible for respiratory sinus arrhythmia (RSA). Divergent shifts in RSA and heart rate are explained by independent actions of DMNX and NA. The theory emphasizes a phylogenetic perspective and speculates that mammalian, but not reptilian, brainstem organization is characterized by a ventral vagal complex (including NA) related to processes associated with attention, motion, emotion, and communication.

Porges (2011) states that polyvagal theory reflected a paradigm that viewed "behavior" as a predominantly top-down controlled process. The physical ("bottom-up") influences within corresponding feedback loops were regarded as minor important, as rather instinctive reactions, e.g. within the well-known "fight-flight" system (Cannon, 1915). However, Porges is strongly interested in the influences of physiology on the psychology of behavior. In this context, he investigated feedback loops of the neuronal regulation of the heart in connection with the two source nuclei of the vagus nerve in the brain stem. Here, the initial focus was on the alteration of *Attention* with reference to heartrate-variability (HRV), later including respiratory rate (Porges, 2009).

Furthermore polyvagal theory is characterized by John H. Jackson's principle of "dissolution" (Konicarova and Bob, 2013). This principle describes the observation that higher developed structures of the brain (and its evolution) inhibit lower levels without these lower levels losing their function and meaning: thus, humans (see "fight-flight principle”) behave in situations of real or perceived real danger in reflexive behavioral mechanisms, the inhibition of which by higher brain parts is then no longer or hardly possible: They “fall back” one step on the evolutionary ladder of the brain, just fighting for their survival. Conversely, the evolution of autonomic control in our human neurophysiology has evolved the complex neuronal integration of the parasympathetic vagus nerves into efferent-motor and afferent-somatic feedback pathways, so that we can assess social situations not only according to an “on-off” principle (safe or dangerous): as mammals we can also fight playfully and use experiences thereby in a variety of social ways. Our autonomic nervous system, and primarily the para-sympathetically acting Vagus Nerves, supports us in practicing social situations (including interactive plays) without too much physiological stress. This is supported by the “vagus brake”, so named by Porges, which allows for a flexible variation between heartbeat and respiration (Porges, 2008). In this context, more variability provides more stress resilience. However, this complex capacity (of the Vagus) also helps us to socially coregulate by supporting facial expressions, speech melody, and other aspects of our body language based on the “Social Engagement System” (SES) (Porges, 2022).

The Polyvagal-Theory and Autism

The Social Engagement System is of importance in understanding autism, since in ASD it is assumed that the autonomic controlling of physiology in interaction with socio-cognitive processes of the frontal cortex cannot support social adaptation (Chua, 2023). In this context, the somatosensory cortex in the parietal lobe of the brain, which has recently been recognized as significant in autism research (Fanghella et al., 2022; Isacoglou et al., 2023) probably also plays an important role, a brain area which is also crucial for language perception processing (Kemmerer, 2023) but, as we assume, also an area of the brain whose insufficient integration with subcortical brain areas prevents the ability to effectively self-regulate stress. The latter is probably the case because altered “mappings” in the so-called “homunculus” (i.e. the mapping of body surfaces) impair the cognitive processing of sensory input via sensory organs and body surfaces in autistic individuals. Furthermore we assume that the processing of visual and auditory inputs also has an effect on self-awareness (proprioception) which is processed in the somatosensory cortex however, there is still little research in this field. (Alonso, 2023). The effect of language development on sensory hyper-responsiveness in individuals with ASD discussed in this article relates (as a consequence of all said above) to a triangle of the (1) neurophysiology of the autonomic nervous system (ANS), (2) the processing in the primary and secondary sensorimotor cortex, and (3) language-processing areas in the cortex that have connections to the limbic system (amygdala) and its connections to the ANS.

Hypersensitivity, Stress, and Language Processing in ASD

In the autism-spectrum, hypersensitivity to sensory input from the environment triggers stress – mostly related to light and sounds, but – as a possible consequence –

also to social signals that cannot be read and assigned with sufficient safety. Stress impairs probably the variable adaptation of ("bottom-up") feedback loops of the ANS in interaction with the ongoing sensory processing, but also in interaction with the language-processing centers in the brain. This is because the language processing areas in the brain are connected to the amygdala in the limbic system, as well as with the processing areas of the sensorimotor cortex (Kemmerer, 2023). Thus, sensory and emotional stress (as registered via the amygdala) also has an effect on language processing in the brain. In this perspective, language processing seems to cause too high "costs" of internal processing for people in the autism spectrum, which may cause a refusal of speech as a medium of social communication. However, it is also possible that language processing is too heavily overlaid by other processing of hyper-sensory-processed input. Sensory signal-processing stress may even lead to an idiosyncratic manner of speech processing: Here, speech becomes a kind of psychomotor-induced release mechanism for compulsive and/or hyper-cognitively controlled speech: the ANS then upregulates the sympathetic nervous system in order to supply the motor systems of speech (Porges et al., 2013). Conversely, this doesn't mean that sympathetic up-regulation can none the more lead to a mitigation of sensorics hypersensitivity: Sympathetic influence does not automatically imply stress in sensorics sensitivity but, on the contrary, a shift in (stress-producing) interoception from sensory to somatic-motoric (heartbeat, respiration, speech musculature) signals. Considered in this way, language can be seen as a hyper-cognitive tool to down-regulate sensory stress. Here we find a hint as to why people with mild autism ("Asperger's autism") can be dominant and sometimes unnervingly long-winded talkers (not just these people, of course!). However, it is important to note, that in this process (described above) a variable down-regulation via para-sympathetic feedback loops may be inhibited, because speech in ASD in these cases is predominantly processed on semantic levels and not understood as a social calming process. This is where Porges' SSP (Safe and Sound Protocol) comes in as a down-regulatory sensory input.

Another study (Porges et al., 2013) evaluated processes underlying two common symptoms (i.e., state regulation problems and deficits in auditory processing) associated with a diagnosis of autism spectrum disorders. Although these symptoms have been treated in the literature as unrelated, when informed by the Polyvagal Theory, these symptoms may be viewed as the predictable consequences of suppressed neural regulation of an integrated social engagement system, in which there is not only down regulation of neural influences to the heart (i.e., via the vagus) and to the middle ear muscles (i.e., via the facial and trigeminal cranial nerves). Respiratory sinus arrhythmia (RSA) and heart period were monitored to evaluate state regulation during a baseline and two auditory processing tasks (i.e., the SCAN tests for Filtered Words and Competing Words), which were used to evaluate auditory processing performance. Children with a diagnosis of autism spectrum disorders (ASD) were contrasted with aged matched typically developing children. The study (Porges et al., 2013) identified three features that distinguished the ASD group from a group of typically developing children: 1) baseline RSA, 2) direction of RSA reactivity, and 3) auditory processing performance. In the ASD group, the pattern of change in RSA during the attention demanding SCAN tests moderated the relation between performance on the Competing Words test and IQ. In addition, in a subset of ASD participants, auditory processing performance improved, and RSA increased following an intervention designed to improve auditory processing.

Function of the SSP

Sensory hypersensitivity is to be mitigated via a calming (acoustic) stimulation of parasympathetically operating Cranial Nerves. The SSP takes advantage of the fact that the innervation of the middle ear not only supplies the auditory cortex with acoustic signals (cochlear nerve and vestibular nerve), but also has an evolutionarily ancient parasympathetic connection to the gillarch via the Facial Nerve (N. F. and its branches). Our middle ear is therefore connected via the N. F. with chewing, swallowing and sucking organs and, of course, also with the vocal organs. Involved in the innervation of the middle ear are also the Glosspharyngeal Nerve (IX: Cranial Nerve, which also innervates the tongue and pharynx) and the Vagus Nerve (X Cranial Nerve), which also innervates the outside of the tympanic membrane. Our listening organ, we might simplify, is parasympathetically innervated and thus a kind of afferent and efferent trigger organ for the ANS. Interestingly enough, via the involved innervation of the Vagus Nerve, we can also better perceive processes of our also viscerally oriented interoception, be it the beating of our own heart, be it the growling of our own stomach.

The music of the SSP is frequency modulated. In this process, frequency components that do not belong to human speech (frequencies that are too low and too high) are filtered out. This makes the music sound a bit like music heard through a telephone line, but with pleasant midrange frequencies and without too high frequency components. The goal is to bring our ANS into contact with the amplified prosodic parts (voice-melodic parts) by especially addressing the above-mentioned nerves of the middle and outer ear innervation.

The primary aim of this study was to evaluate the effectiveness of the SSP on sensory sensitivities and language development 1 week and 4 weeks post-SSP. A secondary exploratory aim was to examine potential differential age effects in the SSP response.

Methodology

Participants

All participants in the study are diagnosed with Autism and all of them are clients of a counseling Practice in the city of Hamburg, Germany. All the children and adults were asked to sign a document that they agree to take part in the study on a voluntary basis. For younger children the parents had to sign the agreement. They got information about the study and the new Safe and Sound Protocol. Table 1 presents the age and number of participants.

Table 1
The Total Number of the Subjects by Age Groups

Age groups	Number
1 gr. 7–11 years old	13
2 gr. 12–18 years old	14
3 gr. 19–50 years old	9
Total	36

The Safe and Sound Protocol Intervention (Heilman et al., 2023)

The SSP was administered either in the presence of a therapist – at a private practice clinic or a private room in the participants' school – or at home by the child's caregivers with therapists' remote supervision. Intervention location was selected by the participants, based on proximity to clinic. Two participants in the clinic group completed 3 sessions of SSP in the clinic and 2 sessions of SSP in the home. In all cases, the SSP was administered for 1 hour per day, for 5 consecutive days. All study participants used a standardized music player with preloaded music tracks for each day of the intervention. The music players were outfitted with high fidelity semi-open over-the-ear headphones with a 53mm diameter speaker with a frequency response of 15 Hz – 28 kHz. Participants were shown how to adjust the volume before listening sessions and instructed to set the volume to a comfortable level.

During sessions provided in clinic or school, therapists were present to provide gentle motivation and non-verbal responses to participants via gestures and mimicry. The private practice room was approximately 22 square meters and outfitted with a sitting area, table, and a soft floor play area. Caregivers generally stayed in an adjacent waiting area during listening sessions but were allowed to be present during listening sessions if deemed necessary to make for participant comfortable. Sessions in the school were conducted in private rooms that included chairs, couches, and quiet games. In some instances, these rooms were not available and sessions took place in the child's typical classroom environment.

Participants who took part in the study at home received the SSP player by mail and aninstructional video was provided online. Prior to beginning the SSP, one of the study authors scheduled a video conference call with the participant or, if the participant was 18 or younger, the participant and a caregiver. During the call, the researcher demonstrated the use of the device, observed the participants as they practiced playing the music, and gave feedback on appropriate activities to do during the listening sessions. Examples of appropriate concurrent activities included coloring, building with blocks, and quiet games without screens (e.g., board games). Computer or mobile phone use, reading, and dancing during listening was discouraged.

Brain-Body Center Sensory Scales (Heilman et al., 2023)

Participants or their guardians completed the Brain-Body Center Sensory Scales (BBCSS; Porges, 2012), a 50-item questionnaire to assess auditory hypersensitivity, auditory hyposensitivity to voices, visual hypersensitivity, tactile hypersensitivity, social touch aversion, digestive problems, selective eating. Subscale descriptions and example items are presented below. Item responses are on a 4-point Likert type scale:
1 = Almost always, 4 = Almost never and include a "not applicable/ not sure" option that is not scored. Subscale scores are calculated by taking the mean of item responses. The psychometric properties, reliability, and validity of the scale has been documented in children and adults with Fragile X Syndrome and ASD (Kolacz et al., 2018).

English-to-German translation of the BBCSS was conducted using a back-translation method. First, two native German speakers with English fluency conducted a forward translation. Both translators were therapists who work directly with ASD clients and their families in Germany. To test fidelity, the resulting German translation was then back translated to English by a native English/German-fluent researcher not involved in the study. The resulting version was evaluated by the first author, who was not involved in either translation. The English source and target text were grammatically and semantically equivalent, with text meaning being preserved during the translation.

BBCSS forms for participants age 18 or younger were completed by caregivers. Participants who were 19 years or older completed the self-assessment except for 2 adult participants with verbal abilities were too low, whose forms were completed by the caregiver. The questionnaires were completed prior to the SSP, one week after the last day of the SSP, and 4 weeks after the last day of SSP. For those participating at a clinic or school, the questionnaires were provided on paper forms. For home use clients, questionnaires were sent by email and participants either submitted their responses by electronic or traditional mail.

The Brain Body Center Sensory Scale (BBCSS) measures Auditory sensory scale , Visual processing scale, Tactile processing scale, Digestive processing scale. We are interested in the connection between the Auditory sensory scale and the *Language ability*, which has the following criteria:

- Non-verbal
- Limited verbal
- Age appropriate.

Results

First Data Collection

The impact of both factors, Age group and Language ability, on the Mean scale values of Auditory Senses scale as a dependent variable is not statistically significant (F(Age group)=.449; p=.508; F (Language ability)=1.75; p=.196).

After 1 Week

After 1 week using the SSP the results do not change. The impact of both factors Age group and Language ability on the Mean scale values of Auditory Senses scale after 1 week as a dependent variable is not statistically significant (F(Age group)=.002; p=.965; F(Language ability)=1.023; p=.321).

After 4 Weeks

Let us look at the results in 4 weeks. The impact of both factors Age group and Language ability on the Mean scale values of Auditory Senses scale after 4 weeks as a dependent variable is not statistically significant (F(Age group)=.014; p=.907; F(Language ability)=3.685; p=.066).

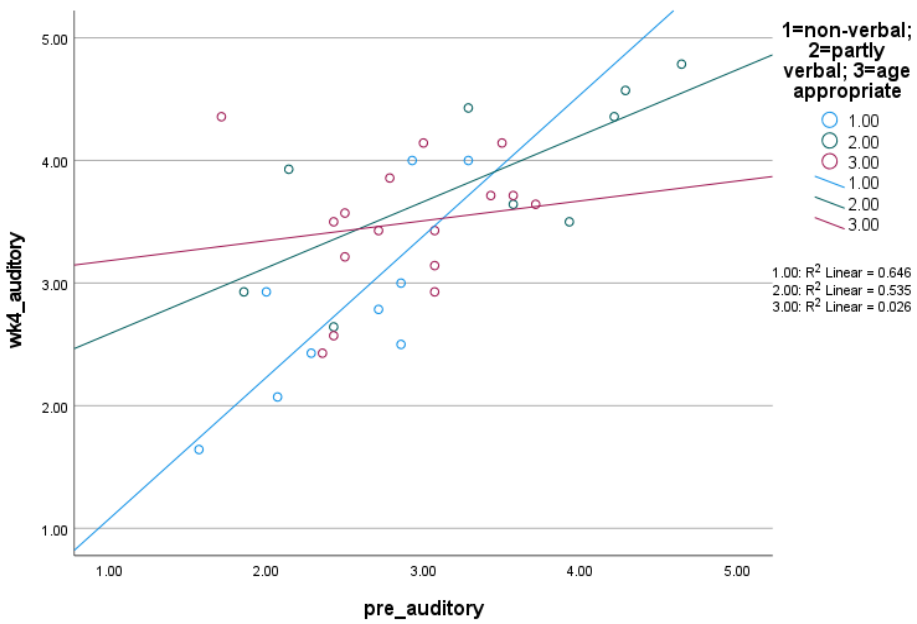
The poorer the language skill, the more linear pre-SSP is to post-SSP. While the individuals with better language skill have flatter regression lines documenting that pre-SSP levels are not strongly related to post-SSP levels. The results are shown in Figure 1.

The impact of factor *Time of data collection* on the Mean scale values of *Auditory Senses scale* as a dependent variable is statistically significant (F(Time of data collection)=4.0133; p=.02112). There are significant differences between First time data collection and data collection after 4 weeks. This is shown in Figure 1. The factor Age group is not statistically significant (F(Age group)=.053; p=.949). The interaction of both factors Age group and Time of data collection is not statistically significant either (F(Age group*Time of data collection)=.247; p=.911).

The impact of factor *Time of data collection* on the *Mean scale values of Auditory Sensory scale* as function of the factor Language ability as instead of dependent variable is statistically significant (F (Time of data collection)=4.0359; p=.02069).

Figure 1

Auditory Sensory Scale as a Function of the Factor Time of Data Collection



The factor Language ability is also statistically significant (F(Language ability)=11.590; p=.00003). This can be seen from Figure 2.

Figure 2

Mean Scale Values of Auditory Sensory Scale as a Function of the Factor Language Ability

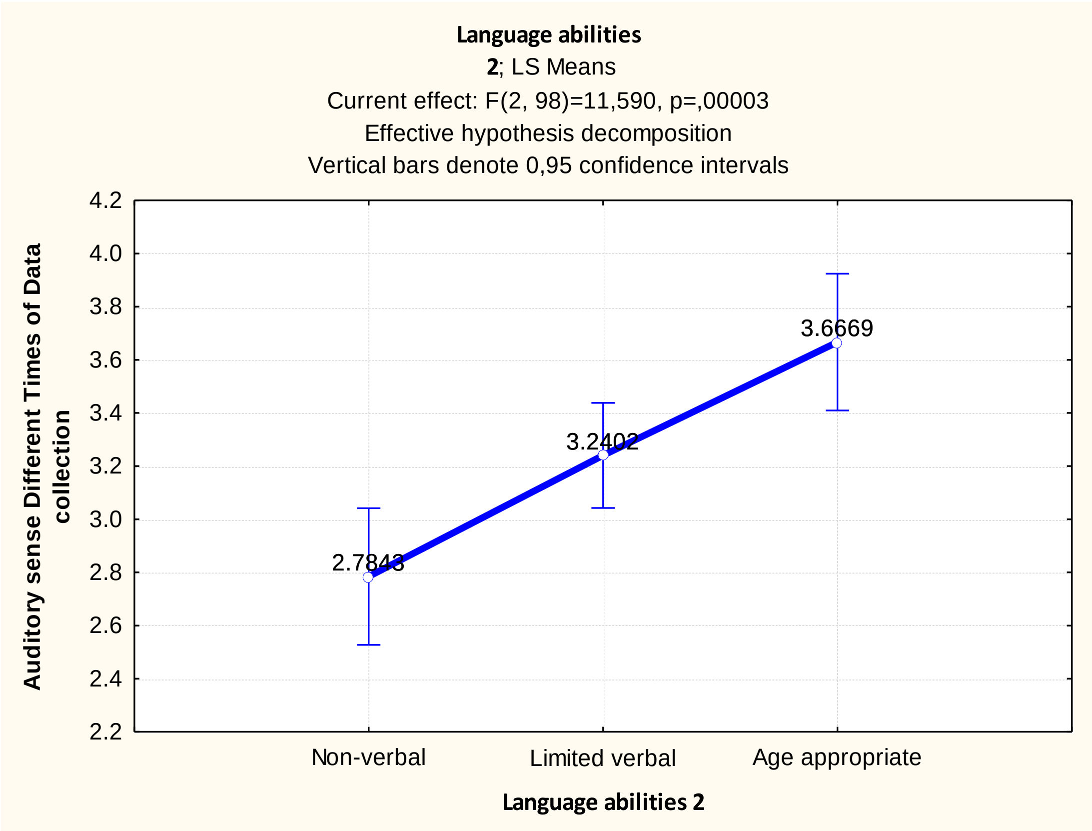


Figure 2 shows that the highest value of the language ability is appropriate to the age. Among all 3 criteria there are significant differences. This can be seen also in Table 3.

Table 3

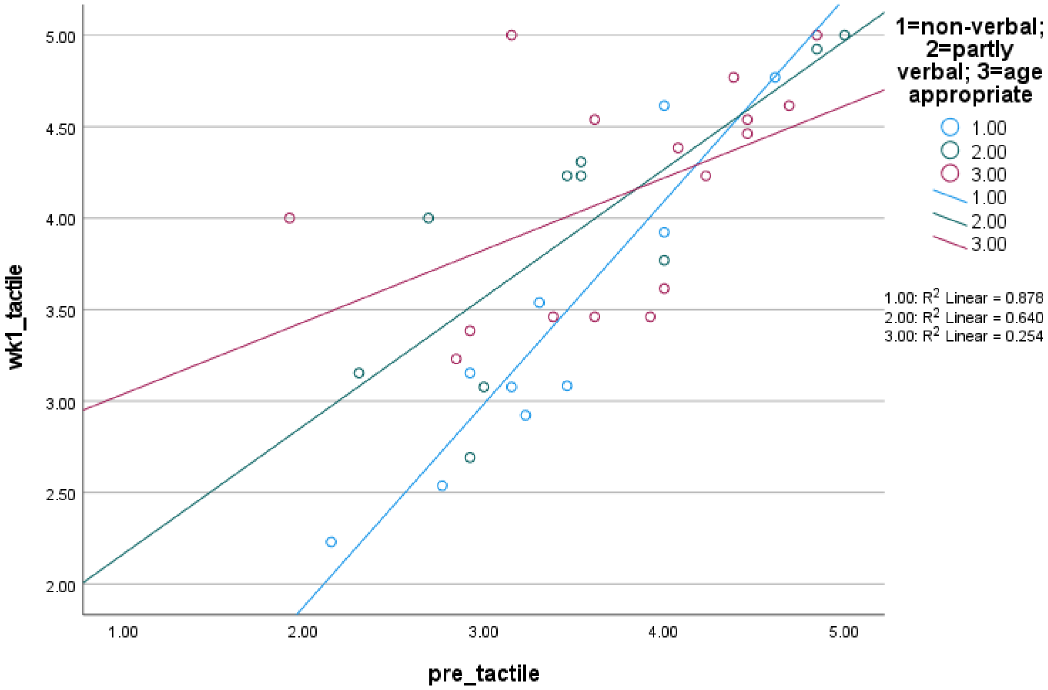
Post Hoc Comparison of Language Ability

Non-verbal		.020841	.000018
Limited verbal	.020841		.031201
Age appropriate	.000018	.031201	

The other significant impact is the tactile hypersensitivities scale which is showing significant differences after the first week testing. The results for the tactile scale are shown in Figure 3.

Figure 3

Tactile Hypersensitivity Scale as a Function of the Factor Time of Data Collection



Discussion and Conclusion

The three sessions with SSP did not help the participants in the research to increase their language abilities. The impact of both factors Age group and Language ability on the Mean scale values of Auditory Senses scale did not have statistically significant results. However, in general we could show, that language ability functions as a mitigating "buffer" against hyper-sensitivity. The factor Time of data collection on the Mean scale values of Auditory Senses scale showed statistically significant results.

In a similar study on Safe and Sound Protocol, Heilman et al. (2023) found out that the short-term effects of the SSP persisted to the 4 week assessment, with additional effects that were detected at the 4 week assessment only. Adolescents and adults had some of the strongest effects in response to the intervention, though all age groups showed improvements. The SSP is based on a theoretical foundation and method that is distinct from other sound therapies, and the effects described here cannot be generalized to any other type of sound therapy. The findings although limited suggest possible therapeutic benefit of the SSP language ability development.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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