Reduce sensorial pain or stress in autism spectrum disorder

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Index

Abstract

Children with autism spectrum disorder (ASD) present challenges in sensory integration that can directly affect their daily lives, as they are not able to organize and/or process the sensory information that enters from the different senses and give a response adapted to their environment.

These processing difficulties in different sensory systems can cause pain or stress. Many people with ASD, in addition to other systems, often have sensory processing difficulties at the auditory level, showing sensory hyper-reactivity reactions to different everyday sounds, both at home and in other settings.

The objective of this study is to show the effectiveness of a tool that helps reduce stress and sensory pain in people with ASD.

An experimental study design with two groups, a control group and an experimental group was used. The instruments for measuring results were the Sensory Processing Measure (SPM), Escala visual analógica de dolor (EVA) and Questionnaire for qualitative measures. As materials, accessible and proportionate tools have been used for the participants, consisting of Bluetooth headphones and a free APP where the sequence is recorded.

Finally, a total of 14 subjects with ASD, with a mean age of 12.4 years, participated in the study. Of these 14 subjects, 10 were part of the experimental group and 4 of the control group. Regarding the total score of the pain scale (EVA), it has been found that it decreased significantly between before and after the intervention. Regarding the total pain scale score (VAS), it was found that it decreased significantly from intense to moderate or mild sensory pain, between before and after the intervention. However, there have been no statistically remarkable differences in terms of auditory sensory processing difficulties obtained from the SPM tool.

In conclusion, the results seem to indicate that the tool used in the intervention favours the reduction of auditory sensory pain in children with ASD in different contexts of their lives.

Keywords: autism spectrum disorder, pain, sensory pain, sensory integration, auditory sensory processing.

1 Introduction

ASD is a neurodevelopmental condition that is characterized by social behaviour deficits and inflexible, repetitive patterns of conduct that are present for early life and which result significant limitations in adaptive functioning (APA, 2013). One of the most limitative aspect of ASD concerns to sensory abnormalities, which are now included in the DSM 5. ASD has heterogeneous causes but, currently, has been established strong genetic basis.

This project search for a comfortable support tool that allow ASD patient decrease limitations caused by sensory abnormalities.

1.1 Neurobiological models of pain

Pain is a complex biological phenomenon that has sensory and emotional components. Pain acts as a warning system to protect us from further harm and allow injured tissues to heal. It also evokes behaviour to bring about relief or comfort. Pain can differ in intensity (raging from mild to severe), onset (sudden to gradual) and duration (lasting from a few milliseconds to moths or even years) (Summers et al., 2017).

Specialized sensory receptors ("nociceptors") in skin and internal organs carry signals along small nerve fiber pathways to the dorsal horn of spinal cord, where they come into contact with interneurons that play an inhibitory or excitatory role. If inhibitory neurons are blocked, secondary projection neurons transmit the nociceptive signal to areas in the brainstem and brain where they are interpreted as pain (Melzack and Wall, 1965). Different brains regions that are involved in cognition, emotion, sensation and pain act together to support the experience and modulation of pain (Ossipov et al., 2010).

In individuals with ASD we can found an important emotional modulation of pain.

1.2 Pain in ASD

1.2.1 Mesuring pain in Individuals with ASD

In verbal individual with ASD. Self-reporting about painful events is possible although sometimes difficult because they expressed different perception. For instance, Ely and colleagues (2016) interviewed 40 children with ASD ages of 6-17 soon after they had undergone a surgical procedure to obtain first-hand accounts about their pain experience. Children were also provided with visual tools to argument their verbal reports by helping them to identify the area of their body that hurt and quantify the intensity of their pain. In terms of strategies used to help to ameliorate their pain, children mentioned distraction, relaxation, taking medication and seeking out their parents.

Questionnaires and rating scales are other methods that have been used to measure pain in different studies. Non communicating Children's Pain Checklist - Revised is the most common.

1.2.2 Pain Experience and Expresion in individuals with ASD

Individuals with ASD seem to have differences in tolerance for pain, in part for their hypo or hyper responsiveness or lack of reactions to a range for positive and negative stimuli, as well as the fact that pain should ordinary act a deterrent for self-harm (Symons et al., 2009).

Allely (2013) conducted a systematic review of research on pain responses in individuals with ASD, finding several case reports that provide some support for pain insensitivity. However, evidence for experimental studies challenged this view and instead suggested that individuals with ASD experience pain but may express in a different or unusual manner.

Moore (2015) examined studies that provided information about the experience of pain and pain expression in individuals with ASD. A review of studies based on clinical observations and experimental investigations using standardized pain stimuli (e.g., electrical or thermal stimulation) failed to yield evidence of hyposensitivity to pain or increased pain threshold in individuals with ASD, but did raise the possibility that they may display different social communicative behaviours during pain episodes. For instance, children with ASD may express negative emotional reactions such as screaming or noncompliance when experiencing pain which could mislead caregivers into looking for non-pain related explanations for their behaviour (Dubois et al, 2017).

1.3 Sensory abnormalities

ASD individuals present sensory integration difficulties. The Theory of Sensory Integration was elaborated in 1960-70 by the occupational therapist Jean Ayres, who described sensory integration as “the neurological process of correctly organizing the sensory information of our senses, both internal and external, in order to give a response adapted to the demands of the environment and achieving adequate levels of development” (Ayres, 1979), pag. 11-15.

Because of this, people with ASD often describe unusual responses to sensory input, such as hypersensitivity to auditory, visual, and tactile stimuli (Blackman, 1999; Grandin, 1996). These autobiographical accounts are corroborated by clinical research that shows higher prevalence of sensory abnormalities among children and adults with ASD when compared to their typically developing and developmentally delayed counterparts (Kern et al., 2006; Kientz and Dunn, 1996; Leekam et al., 2007; Rogers et al., 2003; Tomchek and Dunn, 2007). In fact, unusual responses to sensory input are often considered in ASD assessment algorithms (Lord et al., 1994, 1999; Schloper et al., 1988), also they are included as a criterion for clinical diagnosis (American Psychiatric Association, 2013).

1.3.1 Sensory abnormalities and pain

When the sensorial input that generate hypersensitivity could produce pain responses in individuals with ASD.

In clinical practice, lots of patients with ASD report pain responses to auditory, visual and tactile strong stimuli, this is the most significant symptom because they can feel pain with certain noises (like in a class at school), strong lights (like fluorescent lamps) or tactile stimuli (like seams in some clothes), among others. (Ayres, 1971).

1.4 Auditory frequency and ASD

Attempts to tease apart the multifarious factors that contribute to the expression of ASD has led to interest in how fundamental differences in basic perception may have a bottom-up effect on particular behaviours and difficulties, as well as explain perceived strengths such as in detail-focussed processing (e.g. Milne et al., 2002; Milne et al., 2006; Mottron et al., 2007; Pellicano, Gibson, Maybery, Durkin & Badcock, 2005). Particularly, there is an increasing interest in both the research and academic communities in documenting atypical auditory processing in ASD (Kellerman, Fan & Gorman, 2005; Nieto Del Rincón, 2008; Samson et al., 2006). Auditory perceptual processing can be measured by assessing the ability to discriminate between pure tones that vary systematically according to parameters such as frequency, intensity or duration. To date, it has been reported that individuals with high-functioning autism (mean age 18 years) are superior to controls at frequency discrimination ('same/different' judgement) and frequency categorisation ('high/low' judgement) (Bonnel et al., 2003). The majority of research using event-related potentials (ERPs) suggests enhanced neural detection of frequency changes in ASD at the pre-attentive level (mismatch negativity: MMN) (Ferri et al., 2003; Gomot, Giard, Adrien, Barthélémy & Bruneau, 2002; Kujala et al., 2007), although a clear consensus has yet to emerge for higher-order processing of auditory stimulus changes (P3 waveform) (Ceponiene et al., 2003; Ferri et al., 2003; Gomot et al., 2002). This evidence of enhanced frequency discrimination is further supported by evidence of superior identification of and memory for pitch compared to controls (Heaton, Hermelin & Pring, 1998), as well as enhanced sensitivity for the pitch direction of closely spaced notes (Heaton, 2005).

These findings prompt speculation that fundamental differences in the perception of sounds may be part of the autistic profile (Jones et al., 2009).

This study parts from the mentioned acoustic profile searching for a frequency of sound that acts, like white noise in babies, providing to individuals with a support tool to carry out daily activities without sensorial pain or stress.

2 METHODS

2.1 Study design

The study conducted an experimental design study in which we had a group with access to treatment and a control group awaiting treatment. The distribution in the groups was carried out in a randomized way.

The group awaiting treatment, for ethical reasons, will access it once the study is completed.

Within the design, variables such as the time of use or the context of use of the treatment device were taken into account in order to establish control over these strange variables and open new avenues of investigation.

2.2 Setting

The study reported in this paper was part of a research into the effectiveness of an intervention in people with autism spectrum disorder to reduce sensory pain.

The research was carried out from the Asociación Galega de Asperger (ASPERGA) and in other entities of the Galician community, in the northwest of Spain. This association is a non-profit entity that serves people with autism spectrum disorder and their families at all stages of development.

People in ASPERGA receive individualized or group care adapted to their needs, by a team of healthcare and social professionals.

2.3 Participants

This study was conducted between September 2018 and May 2020; the investigation was interrupted during March and May, since the Covid-19 pandemic occurred during this period. All people with ASD from the Galician community were invited to participate.

The following inclusion criteria were used:

- People diagnosed with some autism spectrum disorder without intellectual or language impairment. (DSM-V).
- Participants aged between 6 and 16 years.
- People who agreed to participate in the study.

- People who have sensory processing difficulties in relation to the auditory system and that interfere with their daily activities.

The initial analysis began with a sample of 98 people who met the diagnostic criteria and who showed sensory processing difficulties. After SPM administration, only 27 of the initial 98 subjects met all the inclusion criteria.

The initial sample of 27 subjects was reduced to 14. Of the remaining 13 participants, 4 have abandoned the intervention due to difficulties in using the tool. The other 9 subjects have also not been included due to the mobility reductions decreed by COVID-19.

TABLE 1. Characteristics of the participating children at initial assessment (n=27)

Sample characteristics	Value, n (%)
Initial study sample	98 (100)
Initial participants	27 (100)
Final study sample with ASD	14 (100)
Experimental group	10
Control group	4
Age (years)	
Mean (SD)	12,4
Range	6-16
Gender	
Male	11 (78,6)
Female	3 (21,4)
Verbal ability	
Presence of verbal language	14 (100)
Presence of sensory processing difficulties	
Auditory sensory pain	14 (100)

The parents or legal guardians of each child received verbal and written information about the research. They were informed that participation was voluntary and that they could withdraw their children at any time. They signed an informed consent form to authorise their children's participation in the study. The confidentiality of the participants was preserved in accordance with the Spanish Data Protection Law.

2.4 Outcomes measures

Questionnaire: to make sensory profiles with unusual responses. SPM Parham, L. D. & Ecker, C. L. (2007). Sensory Processing Measure Home Form. Los Angeles: Western Psychological Services. This questionnaire provides a complete picture of children's sensory processing difficulties at school and at home. This questionnaire evaluates eight areas and sensory systems related to social participation, vision, hearing, touch, taste and smell, proprioceptive system, balance and movement and praxis. This research study has focused on evaluating whether there were sensory processing difficulties at the auditory level.

Pain scale: pre and post pain scale in different social situations (EVA).

EVA allows the intensity of pain described by the patient to be measured with maximum reproducibility among observers. It consists of a 10-centimeter horizontal line, at the ends of which are the extreme expressions of a symptom. On the left is the absence or less intensity and on the right, the highest intensity. The patient is asked to mark on the line the point that indicates the intensity and it is measured with a millimetre ruler. The intensity is expressed in centimetres or millimetres.

The Numerical Scale (EN) is a set of numbers from zero to ten, where zero is the absence of the symptom to be evaluated and ten is its greatest intensity. The patient is asked to select the number that best indicates the intensity of the symptom being evaluated. It is the easiest method to interpret and the most used.

The Categorical Scale (CE) is used when the patient is not able to quantify the symptoms with the previous scales, expressing the intensity of the symptoms in categories, which is much simpler. A relationship between categories and a numerical equivalent is usually established.

Questionnaire for qualitative measures: this questionnaire, prepared by the researchers, describes quantitative data regarding the frequency of App, as well as qualitative data on the context in which it has been used.

2.5 Material

This project aims to generate an accessible tool, so the devices used are in common use by the subjects.

All the subjects used their own smartphone in which they were told to install an Android free app (Frequency Generator).

The app emits HZ additive frequencies and it is the user who chooses the frequency to use, during the material delivery interview, subjects were trained in the use of the app as well as the earphone device.

The headphones chosen to receive the chosen frequencies were Bluetooth earphones with a reception range of 10-20 metres, first of all to avoid snagging and the obligation to carry the smart device always on top. Secondly, to avoid that the device used in this study was a socio economical barrier.

2.6 Intervention

We used an experimental design with a control group awaiting treatment with pre and post treatment measurements in both groups, performed with SPM and EVA.

First of all, we used the questionnaire with subjects and their families to make six study groups: unusual or painful visual responses, unusual or painful tactile responses and unusual or painful auditory responses.

Next, we apply de pain scale in different natural sensorial situations for elaborate a complete sensorial profile.

We only used to this study the group of painful auditory responses.

The participants are provided with the app and the headphones during an individual information session about its use.

Additionally, we used a difference hearing frequency in artificial stressing sensorial situations looking for a frequency that reduce the stress and the painful responses.

The app and the earphone are used for two months in a natural context (school, home, etc.) and, finally, we apply again the pain scale and SPM to compare results in same situation with and without auditory input. In addition, we take the qualitative measurements about time and context of use.

3 RESULTS

3.1 Sensory pain perception

After performing a normal distribution of the data, an effect size measurement was made using Cohen's Delta (Cohen's d) with a result of 0.5 (moderate), therefore, the data is analysed using an ANOVA. of two factors with the results that are exposed next.

Tests of inter-subject effects

Dependent variable: EVA results

Origin	Sum of Squares Type III	gl	Square root	F	Sig.
Corrected model	95,300[a]	3	31,767	11,560	,000
Intersection	1495,032	1	1495,032	544,060	,000
Time	32,232	1	32,232	11,730	,002
Group	14,175	1	14,175	5,158	,032
Time * Group	15,089	1	15,089	5,491	,028
Error	65,950	24	2,748		
Total	1843,000	28			
Corrected Total	161,250	27			

a. R squared = ,591 (R squared adjusted = ,540)

All those results ≥ 0.05 are considered significant; therefore, it is concluded that there is a significant difference both between the pre-intervention and post-intervention measures (time) and between the control and experimental groups.

3.2 Sensory processing

Tests of inter-subject effects

Dependent variable: Sensory processing

Origin	Sum of Squares Type III	gl	Square root	F	Sig.
Corrected model	225,414[a]	3	75,138	2,479	,085
Intersection	115628,929	1	115628,929	3815,612	,000
Time	,914	1	,914	,030	,864
Group	223,214	1	223,214	7,366	,012
Time * Group	2,057	1	2,057	,068	,797
Error	727,300	24	30,304		
Total	137314,000	28			
Corrected Total	952,714	27			

a. R squared = ,237 (R squared adjusted = ,141)

All those results ≥ 0.05 are considered significant; therefore, it is concluded that there isn't a significant difference both between the pre-intervention and post-intervention measures (time) and between the control and experimental groups.

3.3 Auditory sensory processing

Tests of inter-subject effects

Dependent variable: Auditory processing

Origin	Sum of Squares Type III	gl	Square root	F	Sig.
Corrected model	51,464[a]	3	17,155	1,074	,379
Intersection	108665,200	1	108665,200	6800,430	,000
Time	2,800	1	2,800	,175	,679
Group	32,914	1	32,914	2,060	,164

Origin	Sum of Squares Type III	gl	Square root	F	Sig.
Time * Group	8,229	1	8,229	,515	,480
Error	383,500	24	15,979		
Total	135543,000	28			
Corrected Total	434,964	27			

a. R squared = ,118 (R squared adjusted = ,008)

All those results ≥ 0.05 are considered significant; therefore, it is concluded that there isn't a significant difference both between the pre-intervention and post-intervention measures (time) and between the control and experimental groups.

3.4 Other qualitative results

After analysing the data and contributions (references) that the subjects of the sample provide in the questionnaire developed by the investigations, specific results have been obtained on the functional use of the device in different contexts.

Study participants have mentioned having used the tool in various everyday settings, such as in the school setting, at home to reduce stress or sensory pain caused by everyday sounds, and/or as a means of preparation prior to resting and sleeping. Some of the affected subjects have used this device as a means of relaxation and previously to carry out daily activities that generate stress or sensory pain at the hearing level.

This analysis of qualitative data reveals that the tool can be functional and applicable in different environments of daily life of people with ASD between the ages of 6 and 16 years old.

4 DISCUSSION

Numerous research studies describe the existence of dysfunction in sensory integration that people can present when there are problems to modulate, discriminate, coordinate or organize sensations effectively. Specifically, sensory modulation is the ability to regulate and organize the degree, intensity and nature of responses to sensory stimuli in a graduated manner so that they can be used automatically at every moment (Ayres, 1972).

The sensory processing difficulties presented by children with ASD prevent them from responding in a way adapted to the environment around them and, therefore, limit the successful participation in daily activities. (Roley et al., 2015). In the present study, after analysing the results of the SPM, it can determine how the participants present difficulties and / or dysfunction in sensory integration at the level of modulation of auditory stimuli, generating hyper-reactivity towards them. This situation leads to feeling pain or sensory stress when sounds appear.

Unlike the previous literature, the main contribution made in this research was to analyse the results of an intervention between an experimental group and a control group using a tool that reduces the level of stress or sensory pain in the presence of auditory stimuli. Consider it as the first research tested to evaluate the efficacy of such a tool in an experimental group of subjects and to make the comparison with a control group that has not carried out the intervention process.

In previous studies, part of what we are dealing with has been studied, for example the pain response (Alley, 2013) or the pain response centered on a sensory stimulus in the case of tactile (Moore, 2015), based on the information from these studies focus on pain response to auditory stimuli, trying to go one step further and looking for an effective tool. As well as others who worked in the study of the acoustic profile of patients with ASD (Jones, 2009). However, there are no previous studies that, like this one, contribute to describing the efficacy of an accessible tool for people with ASD who have difficulties with auditory sensory processing. We can also consider that it is an accessible tool, both for economic cost and for ease of use, as well as generalizable since it does not require cultural adaptations or adaptations according to the differences of the individuals.

These results should be interpreted with caution due to the following limitations. The main limitation was the small number of the final sample of participants, so the results may not be generalized to the rest of people with ASD in that age range in Spain. Another limitation was the need for greater training in the use of the device, so that the number of participants who dropped out of the study due to difficulties in handling the tool was less.

Finally, this study does not include intervention follow-ups over a longer period of time, since these evaluations could determine the existence of significant differences in the regulation of auditory sensory processing difficulties.

It is relevant to carry out future research to overcome the mentioned limitations. Mainly, implement the experimental design in a sample of the largest population in the entire country, in this way being able to generalize the results obtained and guarantee more solid evidence on the effectiveness of this intervention tool.

In conclusion, this research shows that the application of a tool based on determined auditory frequencies is feasible to reduce the stress and pain that certain auditory stimuli produce for people with ASD between 6 and 16 years of age. In this way, guarantee an improvement in the participation of this group in the different contexts of their lives such as the school, domestic and/or other environments.

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References

- American Psychiatric Association (2013). Diagnostic and Statistical Manual of Mental Disorders (DSM-5), 5th ed.; American Psychiatric Publishing: Washington, DC, USA.
- Summers, J., Shahrami, A., Cali, S., D'Mello, C., Kako, M., Palikucin-Reljin, A., Savage, M., Shaw, O., & Lunsky, Y. (2017). Self-Injury in Autism Spectrum Disorder and Intellectual Disability: Exploring the Role of Reactivity to Pain and Sensory Input. *Brain sciences*, 7(11), 140. https://doi.org/10.3390/brainsci7110140.
- Melzack R. and Wall P.D. (1965) Pain Mechanims: A New Theory. Science 150 (3699).
- Ossipov MH, Dussor GO, Porreca F. (2010) Central modulation of pain. *J Clin Invest.*; 120(11): 3779-3787. doi: 10.1172/JCI43766.
- Ely E, Chen-Lim ML, Carpenter KM 2nd, Wallhauser E, Friedlaender E. (2016) Pain Assessment of Children with Autism Spectrum Disorders. *J Dev Behav Pediatr.*; 37(1):53-61. doi: 10.1097/DBP.0000000000000240.
- Symons, F. J., Harper, V. N., McGrath, P. J., Breau, L. M., & Bodfish, J. W. (2009). Evidence of increased non-verbal behavioral signs of pain in adults with neurodevelopmental disorders and chronic self-injury. *Research in developmental disabilities*, 30(3), 521–528. https://doi.org/10.1016/j.ridd.2008.07.012.
- Allely C. S. (2013). Pain sensitivity and observer perception of pain in individuals with autistic spectrum disorder. *TheScientificWorldJournal*, 2013, 916178. https://doi.org/10.1155/2013/916178.
- Moore D. J. (2015). Acute pain experience in individuals with autism spectrum disorders: a review. *Autism : the international journal of research and practice*, 19(4), 387–399. https://doi.org/10.1177/1362361314527839.
- Dubois, A., Michelon, C., Rattaz, C., Zabalia, M., & Baghdadli, A. (2017). Daily living pain assessment in children with autism: Exploratory study. *Research in developmental disabilities*, 62, 238–246. https://doi.org/10.1016/j.ridd.2017.01.003.
- Grandin, T. (1996). Thinking in pictures. New York: Vintage.
- Ayres, A. J. (1972). Types of sensory integrative dysfunction among disabled learners. American Journal of Occupational Therapy, 26, 13–18.
- Kern, J., Trivedi, M., Garver, C., Grannemann, B., Andrews, A., Salva, J., et al. (2006). The pattern of sensory processing abnormalities in autism. Autism, 10, 480–494. doi:10.1177/1362361306066564.
- Kientz, M. A., & Dunn, W. (1996). A comparison of the performance of children with and without autism on the sensory profile. The American Journal of Occupational Therapy, 51, 530–537.
- Leekam, S., Nieto, C., Libby, S., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. Journal of Autism and Developmental Disorders, 37, 894–910. doi:10.1007/s10803-006-0218-7.
- Rogers, S., Hepburn, S., & Wehner, E. (2003). Parent reports of sensory symptoms in toddlers with autism and those with other developmental disorders. Journal of Autism and Developmental Disorders, 33, 631–642.
- Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the short sensory profile. American Journal of Occupational Therapy, 61,190–200.
- Lord, C., Rutter, M., DiLavore, P., & Risi, S. (1999). Autism diagnostic observation schedule–WPS edition. Los Angeles, CA:Western Psychological Services.
- Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview-revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. Journal of Autism and Developmental Disorders, 24, 659–685. doi:10.1007/BF02172145.
- Schloper, E., Reichler, R. J., & Renner, B. R. (1988). The childhood autism rating scale. Los Angeles, CA: Western Psychological Services.
- Ayres, A. J. (1971). Characteristics of types of sensory integrative dysfunction. American Journal of Occupational Therapy, 25, 329–334.

- Milne, E., Swettenham, J., Hansen, P., Campbell, R., Jeffries, H., & Plaisted, K. (2002). High motion coherence thresholds in children with autism. Journal of Child Psychology and Psychiatry, 43, 255–263.
- Milne, E., White, S., Campbell, R., Swettenham, J., Hansen, P., & Ramus, F. (2006).

  Motion and form coherence detection in autistic spectrum disorder: Relationship to motor control and 2:4 digit ratio. Journal of Autism and Developmental Disorders, 36, 225–237.
- Mottron, L., Mineau, S., Martel, G., Bernier, C. S., Berthiaume, C., Dawson, M., et.

al. (2007). Lateral glances toward moving stimuli among young children with autism: Early regulation of locally oriented perception? Development and Psychopathology,19, 23–36.

- Kellerman, G. R., Fan, J., & Gorman, J. M. (2005). Auditory abnormalities in autism: Toward functional distinctions among findings. CNS Spectrums, 10, 748–756.
- Nieto Del Rincón, P. L. (2008). Autism: Alterations in auditory perception. Reviews in the Neurosciences, 19, 61–78.
- Samson, F.,Mottron, L., Jemel, B., Belin, P., & Ciocca, V. (2006). Can spectro-temporal complexity explain the autistic pattern of performance on auditory tasks? Journal of Autism and Developmental Disorders, 36, 65–76.
- Bonnel, A., Mottron, L., Peretz, I., Trudel, M., Gallun, E., & Bonnel, A. M. (2003). Enhanced pitch sensitivity in individuals with autism: A signal detection analysis. Journal of Cognitive Neuroscience, 15, 226–235.
- Ferri, R., Elia, M., Agarwal, N., Lanuzza, B., Musumeci, S. A., & Pennisi, G. (2003). The mismatch negativity and the P3a components of the auditory event-related potentials in autistic low-functioning subjects. Clinical Neurophysiology, 114, 1671–1680.
- Gomot,M., Giard, M. H., Adrien, J. L., Barthélémy, C., & Bruneau, N. (2002). Hypersensitivity to acoustic change inchildren with autism: Electrophysiological evidence of left frontal cortex dysfunctioning. Psychophysiology, 39, 577–584.
- Kujala, T., Aho, E., Lepistö, T., Jansson-Verkasalo, E., Nieminen-von, W. T., von, W. L., et al. (2007). Atypical pattern of discriminating sound features in adults with Asperger syndrome as reflected by the mismatch negativity. Biological Psychology, 75, 109–114.
- Heaton, P., Hermelin, B., & Pring, L. (1998). Autism and pitch processing: A precursor for savant musical ability? Music Perception, 15, 291–305.
- Heaton, P. (2005). Interval and contour processing in autism. Journal of Autism and Developmental Disorders, 35, 787–793.
- Jones, C. R., Happé, F., Baird, G., Simonoff, E., Marsden, A. J., Tregay, J., Phillips, R. J., Goswami, U., Thomson, J. M., & Charman, T. (2009). Auditory discrimination and auditory sensory behaviours in autism spectrum disorders. Neuropsychologia, 47(13), 2850–2858. https://doi.org/10.1016/j.neuropsychologia.2009.06.015.
- Parham, L. D., & Ecker, C. L. (2007). Sensory Processing Measure Home Form. Los Angeles: Western Psychological Services.
- Roley, S. S., Mailloux, Z., Parham, L. D., Schaaf, R. C., Lane, C. J., & Cermak, S. (2015). Sensory integration and praxis patterns in children with autism. American Journal of Occupational Therapy, 69, 6901220010. http://dx.doi.org/10.5014/ajot.2015.012476