



Humming Can Induce Auditory and Sensory Neurointegration in those with and without Autism Spectrum Disorder

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Abstract

Background: IPNB (Interpersonal Neurobiology) theory puts forth a picture of neuro-disconnectivity in the brain which leads to the development of PTSD after trauma, and is a basis for other disorders including ASD (Autism Spectrum Disorder). Some study of music as stimulation for neurointegration has shown sensory processing improvement, but to date, there has been no formal study of humming for neurointegration.

Methodology: Adults with and without ASD participated in exercises *via* video on a website to determine “felt vibration” and the ability to direct vibration throughout the body in response to music and humming. Questionnaires determined vagal response, emotional and behavioural responses before and after the trials. ANOVA Two-Factor Replication was employed.

Results: Each participant engaged in five days of music-listening, followed by five days of two-part breathing with humming. ANOVA results showed those with ASD listened through bone-conduction more than auditory canal hearing, while those without ASD listened through both pathways. Questionnaire data showed changes in both groups. Those with ASD began to hear high tones, associated with listening through chest, neck and head, while those without ASD began to feel lower tones within the body in response to the humming trial.

Conclusion: Humming may provide more targeted neurostimulation and integration of sensory pathways for both those with ASD and those without ASD. Integration of the two auditory pathways may bypass the bias toward threat processing in those with ASD, allowing for more complete sensory processing and social participation.

Keywords

ASD (Autism Spectrum Disorder); Neurointegration; Humming; Auditory processing

Introduction

An IPNB (Interpersonal Neurobiology) overview states that impaired functioning inside the body impedes flow of energy and information to the brain, body and the outflow of energy which connects one person with another. According to Seigel [1], ensuing rigidity or chaos within the nervous system is the foundation of

mental illnesses, trauma that becomes chronic (PTSD), and autism. This freeze state is also explained in terms of the vagal response of the autonomic nervous system—especially to the heart and prefrontal brain circuits [2]. These circuits are responsible for neuroception, or the assessment of danger in one’s environment, according to Porges [3]. Faulty neuroception stops sensory processing and flow of information to the social circuits in the brain [3]. Here we investigate whether humming, as a self-actuated vibrational therapy, could help repair neuroception in those with ASD (autism spectrum disorder). This study contributes to both the IPNB theory and the study of autism. The literature illustrates the phenomena of sound vibration to create novel brain connections. Johnston et al., [4] state those with autism may have selective hearing which is not easily integrated with visual information, causing errors in sensory processing. It is hypothesized that those with ASD cannot integrate higher pitched sound which comes into the torso, head and ear [4]. This study attempts to delineate any differences in auditory processing between those with ASD and control groups. The aim of this study is to differentiate whether those with ASD listen through bodily “bone conduction” more than their ears. We ask if those without ASD use their ears more than bone conduction? And could humming lead to balanced hearing—using both bone conduction and the auditory canal?

Methodology

Research method and design

Adults with ASD and without ASD were taught to feel vibrations within their body during the music-listening trial, five minutes per day for five days. In the second part, participants were taught two-part (abdominal) breathing, and hum tones similar to those presented in the music. Pre-intervention, mid-intervention and post-intervention questionnaires are designed to measure participants’ felt vibrations and mindful intent to send that energy throughout the body, as well as physiological vagal responses, emotional responses and outward behavioural responses.

The requirement for a release of information regarding clinical ASD diagnosis was bypassed, as all were adults with a history of ASD. The lead investigator assigned numerical representations for the clients with ASD, and no private medical information was obtained from participants. Six adults—3 with ASD, and 3 without ASD—completed the study.

Instrumentation

Questionnaire 1: the IOE (Inner- Outer Experience), includes questions similar to Porges et al. [5] BPQ-SF assessment of internal (vagal) energy, and the ATEC measure of autism symptoms available from the Autism Research Institute (San Diego, CA) (Table 1).

Questionnaire 2: Locating the Self, asks participants about felt music and humming vibrations within the body.

Data was further assessed through ANOVA Two-Factor Replication from the Microsoft Excel data analysis pack.

Website music and humming session participation was monitored by Web-Stat, a tracking service available through Wix.com.

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Received date: December 02, 2020; Accepted date: December 17, 2020; Published date: December 24, 2020

Data collection

All data collection was through online Google Forms. Data collection began after AIRB approval (Argus Independent Review Board, Tucson, AZ) July 29, 2020, and continued through September 17, 2020.

Data analysis

The questionnaires are evaluated for differences in pre and post conditions in each participant, and differences between those with ASD and those without ASD.

Limitations and delimitations

There are no studies involving humming and ASD on which to rely for guidance. Because persons with other neurological disorders, PTSD and even clinical depression may also listen mainly through the secondary (bone conduction) pathway, results from the non-ASD group may be confounded by those conditions.

This study has a very small number of participants which may lead to type II errors due to a skew toward rejecting the null hypothesis.

The use of the internet for a study may change the quality of stimulus to be presented.

These questionnaires were created specifically for this study, and do not represent a complete assessment or best-evidence practice under these conditions. The questionnaires were not tested for internal validity.

Results

Inner-Outer Experience (IOE) (Questionnaire 1)

The IOE number is calculated by adding Inner and Sensory scores together (inner body/vagal problems), and subtracting the Outer/Behavioural (positive attributes) number. This weighs the degree of “inwardness” or vagal reactivity.

Participants with ASD who scored deeper within themselves (than those without ASD), and moved from inner self pre-trial, toward outer self, post-trial (Tables 1-3). ANOVA two-factor with replication shows no significant pre-post changes in those with ASD (n=3), $F(2,12)=2.93, p>0.5$ Failing to reject the null hypothesis, those in the ASD group process sound through bone conduction more than through the auditory canal.

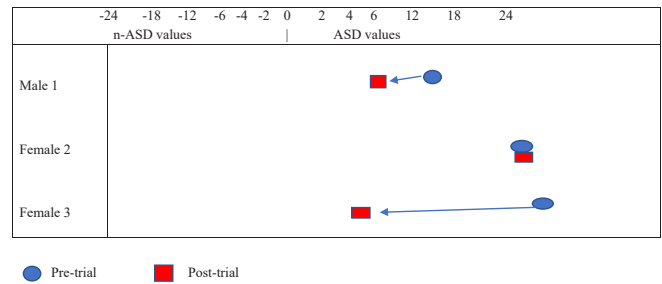
Table 1: Participants with ASD, pre-trial questionnaire 1.

| | Inner/physiology | Sensory | Outer/Behavior | IOE |
|----------|------------------|---------|----------------|------------|
| Male 1 | 11 | 6 | 16 | 1 mild ASD |
| Female 2 | 14 | 10 | 9 | 15 mod ASD |
| Female 3 | 15 | 14 | 17 | 12 mod ASD |

Table 2: Participants with ASD, post-trial questionnaire 1.

| | Inner/physiology | Sensory | Outer/Behavior | IOE |
|----------|------------------|---------|----------------|------------|
| Male 1 | 8 | 4 | 14 | -2 non-ASD |
| Female 2 | 15 | 6 | 6 | 15 mod ASD |
| Female 3 | 12 | 8 | 22 | -2 non-ASD |

Table 3: IOE before and after trial-group with ASD.



The non-autistic participants moved from the outer self, toward inside the self (Table 4-6). ANOVA two-factor with replication, showed no significant effect between music/humming and levels of self, inner, middle/emotional, or outer behaviour, $F(2,12)=23.52, p>0.5$. The null hypothesis is rejected; the non-ASD group does not listen through the ear canal more than through bone conduction.

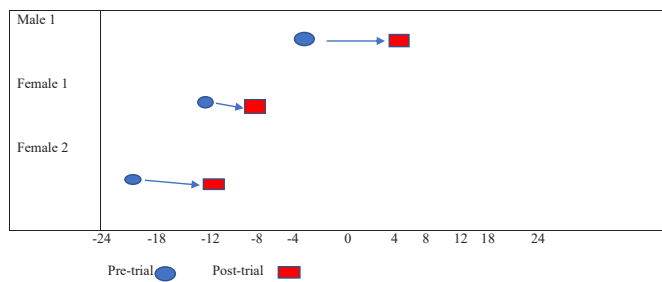
Table 4: IOE Participants without ASD-pre-trial.

| | Inner/physiology | Sensory | Outer/Behavior | IOE |
|----------|------------------|---------|----------------|-------------|
| Male 1 | 13 | 1 | 17 | -4 non-ASD |
| Female 1 | 8 | 3 | 24 | -13 non-ASD |
| Female 2 | 1 | 0 | 24 | -23 non-ASD |

Table 5: Participants without ASD-post-trial.

| | Inner/physiology | Sensory | Outer/Behavior | IOE |
|----------|------------------|---------|----------------|-------------|
| Male 1 | 16 | 4 | 15 | 5 ASD |
| Female 1 | 10 | 3 | 22 | -9 non-ASD |
| Female 2 | 3 | 1 | 16 | -12 non-ASD |

Table 6: IOE before and after trial-group without ASD.



Locating the Self (Questionnaire 2)

Those with ASD showed physiological changes in neck and head in response to humming—they also soon forgot about these effects (Table 7). Those without ASD began to feel low tone vibrations within their body (Table 8).

Table 7: Participants with ASD—felt vibration, zones in the body.

| | 1 | 2 | 3 | 4 | 5 | 6 | * | Narrative |
|----------|------------|---|---------------------------|---|---|---|---|--|
| Male 1 | | | | | | H | | Doesn't everyone feel vibration? The chair is vibrating me. Humming made me see "AV patterns". |
| Female 2 | | | | | | | M | 4 th day Music smelled sweet smell for approximately 30 seconds. Later did not remember listening to music, but did remember that experience. |
| Female 3 | M | M | M | M | M | M | M | Sinuses and thinking clearer after music. After humming visual and hearing seem more in sync. |
| M- Music | H- Humming | | * Could direct vibrations | | | | | |

Table 8: Participants without ASD—felt vibration, zones in the body.

| | 1 | 2 | 3 | 4 | 5 | 6 | * | Narrative |
|----------|------------|---|---------------------------|---|---|---|---|---|
| Male 1 | M | M | M | M | | | | Music 4 th day feel light, like walking in forest. High tones ascending top of trail. Felt tingling in previously damaged/numb nerves. Humming was interrupted at throat level, but like it because I can do it and change how I feel. |
| Female 1 | | M | | M | | | M | Didn't like feeling of vibrations at first. Gradually I started enjoying. Could feel areas 2 and 4 with music. Liked humming best because I could direct vibration to all parts of body and head! |
| Female 2 | | | | | | | | Music very relaxing. Humming required and produced concentration, but I kept forgetting to hum. |
| M- Music | H- Humming | | * Could direct vibrations | | | | | |

Discussion

Through an Interpersonal Neurobiology (IPNB) lens many disorders and psychopathologies may arise from disconnects between brain neuronal pathways and circuits—but it gives a way of viewing root causes and therefore clues as how to begin to work across many seemingly different diagnoses [6]. Work to create a more flexible nervous system is being explored with populations who experienced pre-PTSD traumas, or have developed PTSD.

The questionnaires for this study were designed to relate body functioning with different parts of the vagal nervous system because it is thought that those with ASD suffer from demyelination of the autonomic nervous system [5]. Demyelination would explain a lack of integration of auditory and visual processing frequently seen in those with ASD [7]. While the questionnaires do not specifically measure ASD or non-ASD conditions, they locate where a person is in their body. Low tones resonate deeper within the body [5], and these were charted as “felt vibrations” (Table 7 and Table 8). In general, those with ASD initially felt the low tones vibrating within, suggesting they were seated deeper within the body pre-trial, but moved outward (bodily sensation and behaviours)—a sign of either new pathways or integration of existing sensory systems.

Porges et al. [5] theorizes that when the middle ear is exercised, those with ASD no longer react to the low pitch sounds, and begin

to hear all other frequencies. The Listening Project protocol revealed not only improved auditory processing in those with ASD, but also improved vagal regulation of the heart and the rest of the myelinated social engagement centers in the brain. Our findings agree with previous theory that those with ASD do more “bone conducted”, and less auditory canal hearing—and that humming may be the bridge which connects and balances these two types of hearing for those with ASD [8].

Bone conduction or auditory canal?

In this study, ANOVA confirmed the participants with ASD do listen through bodily tissue and bones more than their ears. The questionnaires showed they also could and did change from both music-listening and humming (Table 9). These perceived changes may be induced by the sound vibration, which can cause both pathways to converge, improving sensory processing [5].

Table 9: Directional movement: An IEO integrative continuum.

| Autism | Non-autism |
|--|------------------------------------|
| 15. 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 ... -23 | |
| Felt vibration post-music changes in head and senses | No (but experienced) |
| Felt vibration post-hum | throat, head |
| ASD group—Inner to outer | Non-ASD group—Outer to inner |
| Male 1 1, -2 = 3 pt movement | Male 1 -4, 5 = 9 pt movement |
| Female 2 15, 15 = 0 pt movement | Female 1 -13, -9 = 4 pt movement |
| Female 3 12, -2 = 14 pt movement | Female 2 -23, -12 = 11 pt movement |

Those without ASD generally felt higher tones vibrating in the outer body zones, such as heart, throat and head. They moved toward awareness of their inner body, according to the post-trial questionnaires. ANOVA results concluded that those without ASD do not listen through the auditory canal more so than through bone conduction.

Raw scores showed changes occurred in those with ASD (n=3), and those without ASD (n=3). There were pre-post differences in both groups, with no significant differences between them. According to the questionnaires, the non-ASD group moved inward to the same degree that those with ASD moved outward (Tables 3 and 6).

Did neurointegration occur?

Reid [9] notes that music vibration hits three afferent nerve fibers which run to the brain, and in turn produce needed hormones and nitrous oxide, needed for cellular and immune functions. Low vibrations increase oxygen pressure in cells, causing immune system activation. This is one type of flow, and of course once cells are invigorated, they create more chemical and electrical activity.

Music-listening leads to neuronal coherence or balance within—vibrations from the music matching neuronal frequencies of the autonomic nervous system, changing heart rate, blood pressure and EEG in accordance to the beat [10]. Humming uses mind, breath, and creates inner vibration. Gerritsen and Band [11] find that mindful

breath directly stimulates vagal action. A filling of the diaphragm, as in the two-part breathing during the humming protocol, also stimulates vagal afferent nerves, resulting in the “rest and digest” response, increasing neuroconnectivity and flexibility [11]. Increased oxygenation through continuous breathing can also bring people out of a “frozen within” state [6]. Other studies have found that breathing with a fast exhale can increase threat response [12]. Other outcomes from abdominal breathing, according to Gerritson and Band [11], includes flow to the posterior brain for more complete processing of not only auditory information, but emotions, pain, vision and more.

Whether it is actually movement, or breath, or being mindful which empowers one to create new neuroconnections or process sensory information in a different way, was a question posed by Gomutbutra et al. [13]. Their meta-study showed meditation through movement such as Tai Chi, modifies the production of the brain hormone BDNF. This hormone is thought to be responsible for producing neural plasticity. We concur that more than mere concentration on feeling music vibration, humming promotes action and movement from within. Although short mindfulness-based meditation and body scanning can create changes in brain function and structure, Gomutbutra et al. [13] states that these alone generally do not raise BDNF production. Physical movement was thought to be the rate limiter for production of the brain hormone.

The Porges et al. [5] theory that demyelination of the upper vagal pathways in those with ASD, combined with the Johnston et al. [4] concept of blocked neuroception from felt vibration through the heart, head and ear, may be representative of those with ASD who were unable to “feel” the higher frequency sounds (Table 7). Seeing “AV-patterns” during humming was the experience of one ASD participant, and can occur in response to a restoration of auditory pathways previously depleted [14]. Could the responses seen in the ASD group be due to remyelination of the brain where the bone conduction and auditory canal signals integrate to one auditory representation?

Previous studies show exposure to both high frequency electric and light stimulation in rats can produce oligodendrite activity resulting in neuronal myelination after just 30 minutes with longer exposure creating a cascade of changes lasting weeks [15]. Music-listening alone recruits many parts of the brain such as semantic memory, locating and motor functions, relying mostly on bilateral functioning and can result in strengthening neuronal connections [16].

To repair neuroception in those with ASD, detecting and decoding vibrational sound through the upper body and head may be better achieved through humming. All participants were able to experience a positive effect from listening to music and humming, even if they could not feel the vibrational action in the body (Table 9). Because humming was self-directed, those who could feel it working for them were most interested in humming. Others found the concentration on their inner body taxing, so preferred music-listening. Both conditions apparently offered vibrational coherence to all participants.

In conclusion, those participants without ASD used both bone conduction and their ears to listen. Participants with ASD had a

propensity to process sound through bone conduction. Through humming, they also moved toward their outer self, feeling vibration near the heart and throat where they could not before.

According to the IPNB theory, a lack of integration and flow exists in a person with ASD. Through normal development a child integrates sensory processing, resulting in a smooth “flow” and function. This may be reversed through coherence achieved through vibrational action on the vagal nervous system to calm the threat response [12]. Our humming trial may possibly be showing an integration of both bone conduction and auditory canal hearing in those with ASD—resulting in energy flow through the brain processing centers. Humming may be superior to music-listening, because it apparently acts as an integrating force through the primary and secondary auditory pathways, to surpass the threat processing bias which exists in most persons with ASD [5].

Much more study is needed to more closely align the concepts of vibrational energy and neurogenesis. This study was a step into a new arena, with hopefully more to follow. Future study could look at differences between music-listening and humming. Suggesting that those with ASD have a predilection to listen through bone-conduction does not rule out that persons without ASD may also listen more with their body. Any studies that can quantify these phenomena are needed.

Conclusion

Humming may provide more targeted neurostimulation and integration of sensory pathways for both those with ASD and those without ASD. Integration of the two auditory pathways may bypass the bias toward threat processing in those with ASD, allowing for more complete sensory processing and social participation.

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