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The Effects of Sensory Integration on Short Term Memory in College Students

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Abstract

Recent research has shown Sensory Integration Dysfunction to be a major contributing element in difficulties associated with many childhood disabilities including Autism Spectrum Disorders. Additionally, many difficulties faced by general education students in regular classrooms have been linked to Sensory Integration Dysfunction. The original focus of sensory integration research was on children; however, recent studies are now exploring other populations such as aging adults and young adults. A sample of 157 undergraduate students was randomly assigned into three groups to test the link between short term memory and increased sensory integration. Results indicated a difference between the "visual/auditory" group and the "visual/auditory/vestibular" group. Implications of these findings are discussed.

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The concept of sensory integration was first explored in the 1970s by Dr. Jean Ayres in the context of learning disorders. Her theory was based on a definition of learning disorders as a reflection of "some deviation in neural function" (Ayres, 1977, p. 1). Her theory stated that such deviations could be lessened through rewiring neural activities that were not adequately or accurately connecting through fostering sensory integration (Ayres, 1977).

As defined by Ayres, sensory integration is the "neurological process of organizing information we get from the senses" (Kranowitz, 1998). Organizing information from all the senses requires a large portion of the brain because different senses involve different neural areas. In fact, over 80% of the brain is involved in regularly functioning sensory integration (Ayres & Robbins, 2005).

In any discussion involving sensory integration it is important to have a basic understanding of all the human senses. The five basic senses (i.e., hearing, seeing, smelling, tasting, and touching) have also been termed "far senses" because they are used to detect and interpret external stimuli coming into the body from the outside environment (Kranowitz, 2003, p. 39). In addition to the far senses, there are four "near senses" as well: the tactile, interceptive, vestibular, and proprioceptive senses (Kranowitz, 1998, p. 40-41). These near senses are used to perceive and interpret internal stimuli. The tactile sense is the near sense by which we process information received by touch primarily through the skin (Kranowitz, 1998). The tactile sense is different than the sense of touch primarily because it is largely unconscious. For example, you reach out with your hand and consciously sense the feeling of sandpaper with your fingers through the sense of touch. You unconsciously recognize the seat you are sitting on through your tactile sense

(Kranowitz, 1998). The interceptive sense is the sense by which people perceive internal organs and bodily feelings such as one's heart rate or the feeling of hunger (Kranowitz, 287, 1998). The vestibular sense is the sensory system that allows humans to process information about balance and movement. The proprioceptive sense is intricately connected to the vestibular sense and is the method by which humans sense and perceive information about where the body is in relation to itself and its surroundings through the muscles, bones, ligaments, and skeleton (Kranowitz, 1998).

The vestibular sense, how humans sense where their bodies are in relation to space, is also very important in other cognitive functions. Many studies have been done to prove that dysfunction in the vestibular sense leads to decreased cognitive abilities that include decreased object recognition and numerical cognition (Hitier et al., 2014). It has also been proven that vestibular input is necessary for the working memory system to sufficiently process spatial cues to form accurate spatial memory (Aversano et al., 2002).

Sensory integration, sensory integration dysfunctions, and therapies surrounding sensory integration dysfunction have be gaining recognition in many fields in recent years. Most of the research regarding sensory integration pertains to Sensory Integration Dysfunction or to Autism Spectrum Disorders. Though a child who has Sensory Integration Dysfunction does not necessarily have an Autism Spectrum Disorder, the two are closely linked in that most children with an Autism Spectrum Disorder do have some issues with sensory integration (Kranowitz, 1998). Depending on the severity of the Autism Spectrum Disorder, a child's sensory issues may be less severe than Sensory Integration Dysfunction. The reason that most research involves Sensory

Integration Dysfunction instead of well-functioning sensory integration is that a lack of normally functioning sensory integration is much more visible than its presence (Kranowitz, 1998).

Unlike sensory integration, research regarding short term memory is well-established. For something to be in short term memory it has to be in one's memory for no more than 30 seconds (Rosenzweig et al., 1993). The average short term memory is seven items, meaning that a person can, on average, store up to seven items (e.g., nonsense syllables, digits) in his or her short term memory (Kaminisk et al., 2010). A person's short term memory can be improved by creating new neural pathways or strengthening existing pathways. This can be achieved by learning something new or continuing to practice and improve at something that has been a part of one's life for some time. Practicing an instrument, learning to knit, or simply taking a new route home all strengthen or create neural pathways. Short term memory can also be improved through practicing memorization. In the current age of cell phones that talk and remember things for you (from phone numbers to shopping lists), many of the most common tasks for short term memory have evaporated. With contact lists and shopping apps, there is little need to try to remember phone numbers and grocery items on your own, except for the fact that such aims would improve neural pathways.

Dr. Ayres' theories were first applied to children, however in more recent years, Sensory Integration Therapy has been applied to adults with learning disabilities as well (Brocklehurst-Wood, 1990; Dave, 1992; Reisman, 1992; Urwain-Ballinger, 2005). Such studies have shown vast improvement in multiple areas that present difficulties for adults, and indeed children, with learning disabilities: improved focus, reduced self-injury, and improved self-stimulation (Urwain-Bellinger, 2005). The effects of sensory integration on neural capabilities of those who are on the Autism Spectrum are vastly different than the effects of sensory integration on those who are not on the Autism Spectrum. Because of this fact, the research conducted on using sensory integration therapy for the treatment of Autism Spectrum Disorders is not included here. This paper does, however, explain research on other learning disabilities. Studies about the effects of sensory integration on the individuals who do not have any type of learning disabilities are few and far between. In our review of current literature, we were unable to find any study considering Sensory Integration's possible effects on short term memory. Because the present study is primarily interested in the association between task performance and short term memory, we examine here research studies that involve similar measures of assessment, that is to say performance, instead of brain scans such as EEGs and MRIs. Mahoney, Li, Oh-Park, Verghese, and Holtzer (2011) conducted a study that was similar in nature and goal to the present study.

Mahoney and colleagues (2011) considered multi-sensory integration in young and old adults and its effect on reaction time. Their study included two groups of eighteen adults. One group had an average age of 76.44 years. A second group of eighteen adults had an average age of 19.17 years all of whom were determined to be non-demented by their Mini Mental State Examination (MMSE) scores (Mahoney et al., 2011). As far as we know, Mahoney and colleagues were the first to report on the effects of sensory integration across auditory, visual, somatosensory, integration for young and old adults without neural deficiencies (Mahoney et al., 2011). Nevertheless their results were consistent with other studies that considered only young adults (Harrington & Peck, 1998; Molholm et al., 2002; Teder-Salejarvi et al., 2002; Murray et al., 2005; Pavani et al., 2000) as well as studies that considered older adults (Laurienti et al., 2006; Peiffer et al., 2007). These results were that reaction time was better with multi-sensory integration than it was with uni-sensory conditions. Studies such as these offer support that improvement can be achieved in neural activity in a brain even when there is no diagnosed deficiency in a person's current capabilities which indicates that short term memory can be improved. Mahoney et al. (2011) did not, however, suggest any direct link to an educational environment, which is possible with the current study. Mahoney et al. (2011) studied reaction time. The present study considers short term memory.

Since Dr. Ayres pioneered sensory integration therapy and research in the 1970s, many strides have been made in therapy for children and adults with learning disabilities. Sensory integration has not yet made its debut into general education classrooms or the everyday lives of the majority of the population, though studies do suggest it has potential to vastly improve such situations. The present study begins to show ways that sensory integration can infiltrate and improve life in all classrooms (special needs and general population classrooms as well).

Any link between sensory integration and short term memory is important to investigate because of the many implications it will carry. In the present study we look at a single cognitive function: short term memory. Other studies have considered different cognitive functions with different populations and with a specific sense, or sensory integration therapy that has been performed before the cognitive task. The present study looks at the effects of sensory integration during the short term memory task.

Materials and Methods

Sample

One hundred fifty-seven undergraduate students enrolled in a 200-level Human Development course at the University of Tennessee, Knoxville, were the participants in the present study. The participants ranged in age from 18-29. Their participation was entirely voluntary and no monetary compensation was given. Additionally, their participation was not a requirement of the course, though they were able to receive 2-points of extra credit if they participated in this research study. Participant ages are summarized in Table 1. Group distribution is summarized in Table 2.

Table 1. *Age of Participants*

Age	Number of Participants
18	7
19	90
20	33
21	14
22	7
23	3
24	1
25	1
29	1

Table 2. *Distribution of Sample into Groups.*

Cumulative Percent	Frequency	Percent	Cumulative Percent
(1) Visual Only	53	33.8	33.8
(2) Visual/Auditory	53	33.8	67.5
(3) Visual/Auditory/Vestibular	51	32.5	100.0
Total	157	100.0	100.0

Materials

For the purposes of the current study we needed 14 flashcards of nonsense syllables. These were randomly split into two sets that remained constant throughout the study for all three groups. A stable chair was used for those participants randomly assigned to the "visual only" group and the "visual/auditory" group. For participants in the "visual/auditory/vestibular" group, we asked them to sit upon a standard exercise ball while performing the task.

Procedures

Upon arrival, participants were asked sign in, draw a number (which would become their participant number) out of a bowl, and fill out the informed consent document. All participants were given copies of the informed consent document that they signed. The bowl from which they drew their participant numbers contained 200 different numbers. By this method, we randomly assigned students to one of three possible groups. Students who drew numbers that began with one zero (number from 01-070) were assigned to the "" group, meaning that they would only be allowed to <u>look</u> at the flash cards with nonsense syllables and later asked to try to remember the syllables they had been shown. Students who drew numbers that began with two zeros (numbers from 001-0070) were assigned to “visual/auditory group,” meaning that they would look at the flash cards and also read the nonsense syllables aloud, thus engaging both the visual and auditory senses. Students who drew numbers that began with three zeros (numbers from 0001-00070) were assigned to the “visual/auditory/vestibular” group, meaning that during the task they would be balancing on a standard exercise ball while they looked at the cards. Participants in this group also read the syllables aloud, thus engaging the visual, auditory, and vestibular senses.

All participants were shown the same two sets of seven nonsense syllables. These syllables all contained three letters each and were shown to all participants in the same order. Each participant in the “visual only” group was informed that s/he would be shown a series of nonsense syllables. S/he was instructed to look at the nonsense syllables quietly and remember as many as s/he could. As soon as s/he was shown all seven cards, the participant was asked to repeat all the syllables that they could remember in any order they could remember them. The total number of nonsense syllables correctly recalled was recorded. The test was then repeated with a second set of seven nonsense syllables.

Each participant in the “visual/auditory” group was informed that s/he would be shown a series of nonsense syllables which s/he was to read out loud and try to remember. As soon as the participant had been shown the set of seven, s/he was asked to repeat all the syllables that s/he could remember in any order s/he could remember them. The total number of nonsense syllables recalled was recorded. After the results were recorded, the test was then repeated with the second set of seven nonsense syllables.

Participants assigned to the “visual/auditory/vestibular” group were first asked to move out of the stationary chair in order to sit on an exercise ball. The researcher also shifted positions to be directly across from the student, as she was for the "visual only" group and the "visual/auditory" group. Each participant was instructed to stay far enough back from the table that s/he would not be tempted to use the table for balance. The participant was then informed that s/he would be shown a series of nonsense syllables that s/he was to read out loud and try to remember. Immediately after being shown the set of seven syllables, the participant was asked to repeat back as many of the syllables as s/he could remember in any order s/he could remember them. The total number of syllables remembered was then recorded. The test was repeated with a second set of seven nonsense syllables.

Results

We first ran a frequency test for participant numbers, to check for errors in data entry. In this manner, we determined that three participant numbers were repeated. The duplicates did not appear to recall the same number of syllables. Thus, it was concluded that the data was not entered twice, but rather the first participant's number had gotten tossed back into the bowl of numbers. For each of the three numbers that had a duplicate, we created a new participant number for the second participant with the same number, and both participants' data were retained for further analysis.

A Chi-Square Test was first implemented to analyze the differences among the three groups. This showed a *p*-value of 0.07, which approaches significance but remains statistically insignificant.

Following the Chi-Square Test, we ran independent samples *t*-tests to examine between-groups difference. The *t*-tests indicated no statistically significant difference between the "visual only" group and the "visual/auditory" group. Nor was there a difference between the "visual only" and the "visual/auditory/vestibular" group. A third *t*-test between the "visual/auditory" group and the "visual/auditory/vestibular" group showed a statistically significant difference of *p*=.05. Table 3 gives detailed results of the *t*-tests.

Comparison	*t*-value	*p*-value
visual only vs. visual/auditory	-1.69 (.190)	0.08
visual only vs. visual/auditory/ vestibular	-.245 (.221)	0.795
visual/auditory vs. visual/ auditory/vestibular	1.35 (.198)	0.05

Table 3. *Results of Independent Samples t-tests.*

Discussion

We found a statistically significant difference (*p*=.05) between the "visual/auditory" group, for which participants read the nonsense syllables aloud while sitting in a stable chair, and the "visual/auditory/vestibular" group, for which participants read the nonsense syllables aloud while balancing on an exercise ball. The statistical analysis revealed that the visual/auditory group performed better on the Short Term Memory test than the visual/auditory/vestibular group.

It is also important to note that, though the design of the experiment was intended to have the **"**visual only**"** participants receiving only visual stimuli, the room in which we conducted the experiment was not often totally quiet. Therefore, it is likely that many of the participants in Group 1 did receive some measure of auditory stimuli, even though these stimuli were not directly related to the short term memory task at hand. Because the other groups also had the additional auditory stimuli, it was a factor that was kept constant among all three groups.

Many researchers in recent history have shown that deficits in sensory integration and also specifically in the vestibular system lead to impaired cognitive functions in animals and in humans (Aversano et al., 2002.; Smith & Zheng, 2005; Urwin & Ballinger, 2005). Many of these deficits are spatial in nature: impaired spatial navigation, spatial learning difficulties, spatial learning etc. These findings make sense because the vestibular sense is used to detect and analyze spatial cues, which is the way humans sense where their bodies are in space. The vestibular systems effects, however, have been proven to reach far beyond the spacial realm (Smith et al., 2009; Smith & Zheng, 2005; Urwin & Ballinger, 2005). Animal studies have proven very useful in studying the effects of vestibular lesions. A study which looked at rats' ability to navigate mazes six months after undergoing Bilateral Vestibular Differentiation show that the effects of vestibular differentiation on spatial memory might be lasting (Smith et al., 2009). Though the previous study discussed cannot eliminate the possibility that the damage to the rats' memories was not due, at least in part, to damage to the auditory system, other studies have shown that the effects of auditory lesions and vestibular lesions on memory and intelligence were separate and distinct (Smith et al., 2009).

Though some human studies have revealed effects of vestibular lesions, they did not examine non-spatial aspects of memory or general intelligence, and other studies reported permanent repercussions including dyscalculia (Smith et al., 2009). It has also been shown that people with vestibular disorders display an array of different cognitive deficiencies including impaired object recognition memory (Hitier et al., 2014). Brain-imaging studies have also shown that people living with vestibular disorders often experience cognitive dysfunction that is not immediately associated with dizziness or vertigo, two indications of a problem in the vestibular system (Smith et al., 2005) This finding indicates that those who have learned to compensate for their vestibular disorders do not always feel the effect of the vestibular system misfiring in the common ways of dizziness and/or vertigo. Nevertheless, such individuals may still experience some cognitive effects of their vestibular dysfunction.

Hitier and colleagues' (2014) published a study examining the different pathways involved in vestibular stimulation. Other studies had previously revealed that rodents, felines, monkeys and also humans have at least nine areas of the brain that play some role in the vestibular system—most of them having a significant effect on the subjects spatial cognition (Hitier et al., 2014). Any person who has spun in circles until they perceive the room to be spinning around them (vestibular-induced-vertigo) knows that while in this state of extreme dizziness, simple physical tasks such was walking in a straight line are extremely difficult and simple cognitive tasks such as basic mental math are near unthinkable. This difficulty is due to the fact that these nine vestibular cortices play roles other than spatial reasoning and sensation. Object recognition and numerical cognition are also suspected to be effected by vestibular input (Hitier et al., 2014).

Based on the findings of previous studies that indicate improved cognitive abilities with improved sensory integration and, specifically, the introduction of vestibular input, we hypothesized that, by instructing some participants to sit on a ball, participants in the visual/auditory/vestibular group would be forced to engage of their vestibular sense more drastically than those in the "visual only" and the "visual/auditory" groups and they would, in turn, display increased cognitive ability—specifically, increased short term memory. By using nonsense syllables instead of numbers or ordinary words, we eliminated the possibility of recognition or connection to previous history or of some mathematical system of memory (such as adding the numbers together or making an equation out of the random digits). This study's findings, however, show that the "visual/auditory" group performed better than the "visual/auditory/vestibular" group.

These results contradict the hypothesis that increased sensory integration increases short term memory.

This finding could be due to several different options. The first of these possible causes is simple distraction. If the participants in the “visual/auditory/vestibular” group were, on average, paying more attention to the exercise ball itself than the nonsense syllables, their distraction could have decreased their Short Term Memory capacity.

Another possible cause for the decreased performance on the memory test for the participants in the “visual/auditory/vestibular” group is confusion. All the participants knew that they were going to participate in a Short Term Memory study. Participants in the “visual only” group and the “visual/auditory” group most likely experienced something similar to what they expected: being asked to remember something while sitting on an ordinary chair. Participants in Group 3 often displayed some amount of confusion as to why they were being asked to sit on an exercise ball. Had they been focusing on what they deemed to be an oddity and not concentrating on the task at hand, their results might also have been affected.

Additionally, it is possible that vestibular input received at the time of the memory task does have a negative effect on short term memory. Previous studies have focused on cognitive ability after sensory input is either increased, decreased, or physical disrupted or improved through therapy. A test of short term memory during the stimulation might alter those results repeatedly. The positive effects of increased sensory integration capacity on cognitive abilities is well established. Further tests need to be done before we can conclude that increased sensory input at the time of cognitive tasks is proven to have negative effects on cognitive abilities. The present study considered only short term memory, similar studies that test the effect of increased sensory input on other cognitive tasks such as object recognition and numerical cognition also need to be conducted.

Other tests need to be conducted to either support or contradict our results. First, we were testing a very specific population: college students. Our participants ranged in age from 18 to 29 with approximately 57.32% of our participants being age 19. Additionally, though we did not run analysis of this data, we suspect that females were significantly over-represented and males were significantly under-represented. Because of these two facts, more studies need to be conducted that consider a wider population with participants across a wider age range and that either consider males and females separately or have both genders represented equally.

Dr. Ayres' theories have proven extremely useful in the treatment of autism, sensory processing disorder, and learning disabilities as a whole. Similarly, sensory integration has been used to help improve neural functions of adults as they age and, possibly, lose some of their previous disabilities (Mahoney, Li, Oh-Park, Verghese, Holtzer, 2011). Dr. Ayres' theories have not, however, been used to improve the mental capacities of those who do not have such deficiencies in their neural pathways—regardless of the fact that doing so will likely be extremely helpful in everyday life of an adult or a student in all levels of education. This is especially true given that improving the human brain, even one without any defects, is possible. Despite the above limitations and the discrepancies between our data and that found by previous researchers, our study is a valuable body of knowledge in several ways. Though our results do not prove the direct link between short term memory and sensory integration in that as one increases a person's sensory integration it is yet unclear if short term memory will also increase, we have shown that altering the amount of sensory information a person receives during a memory task does have an effect on short term memory. Though further research is still needed to determine what that link is and how it can best be used to improve daily lives of individuals, our research has proven that the link does exist.

References

Altieri, N., Townsend, J. T., & Wenger, M. J. (2014). A measure for assessing the effects of audiovisual speech integration. *Behavior Research Methods, 46*(2), 406-415. doi:10.3758/s13428-013-0372-8

Aversano, M., Sacchi, R., Memoli, R., Graziano, A., & Petrosini, L. (2002). Anterograde and retrograde influence of vestibular stimulation on spatial working memory. *Physiology & Behavior, 76*(4-5), 655-660. doi:10.1016/S0031-9384(02)00787-4

Bates, S. L., & Wolbers, T. (2014). How cognitive aging affects multisensory integration of navigational cues? *Neurobiology of Aging,* doi:10.1016/j.neurobiolaging.2014.04.003

Gilmartin, M. R., Balderston, N. L., & Helmstetter, F. J. (2014). Prefrontal cortical regulation of fear learning. *Trends in Neurosciences,* doi:10.1016/j.tins.2014.05.004

Hitier, M., Besnard, S., & Smith, P. (n.d.). Vestibular pathways involved in cognition. *Frontiers in Integrative Neuroscience, 8*(59). 1-16, doi: 10.3389/fnint.2014.00059

Lisman, J., & Idiart, M. (1995). Storage Of 7 /- 2 Short-term Memories In Oscillatory Subcycles. *Science, 267*(5203), 1512-1515. Retrieved October 21, 2014.

Ono, Y., Nomoto, Y., Tanaka, S., Sato, K., Shimada, S., Tachibana, A., . . . Noah, J. A. (2014). Frontotemporal oxyhemoglobin dynamics predict performance accuracy of dance simulation gameplay: Temporal characteristics of top-down and bottom-up cortical activities. *NeuroImage, 85*, 461-470. doi:10.1016/j.neuroimage.2013.05.071

Rosenzweig, M., Bennett, E., Colombo, P., Lee, D., & Serrano, P. (n.d.). Short-term, intermediate-term, and long-term memories. *Behavioural Brain Research,* 193-198. doi:10.1016/0166-4328(93)90135-D

Smith, P., Brandt, T., Strupp, M., Darlington, C., & Zheng, Y. (2009). Balance before Reason in Rats and Humans. *Annals of the New York Academy of Sciences,* 127-133.

Smith, P., Zheng, Y., & Darlington, C. (2005). Does vestibular damage cause cognitive dysfunction in humans? *Journal of Vestibular Research: Equilibrium & Orientation, 15*(1), 1-9. doi:10.3389/fnhum.2013.00678

Stonefelt, L. L., & Stein, F. (1998). Sensory integrative techniques applied to children with learning disabilities: An outcome study. *Occupational Therapy International, 5*(4), 252-272. doi:10.1002/oti.80

Urwin, R., & Ballinger, C. (2005). The effectiveness of sensory integration therapy to improve functional behaviour in adults with learning disabilities: Five single-case experimental designs. *The British Journal of Occupational Therapy, 68*(2), 56-66. Retrieved from http://search.proquest.com/docview/620709464?accountid=14766

Weinberger, N. M., Miasnikov, A. A., Bieszczad, K. M., & Chen, J. C. (2013). Gamma band plasticity in sensory cortex is a signature of the strongest memory rather than memory of the training stimulus. *Neurobiology of Learning and Memory, 104*, 49-63. doi:10.1016/j.nlm.2013.05.001