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A Preliminary Review of Vestibular Impacts on Upper Extremity Abilities of People with Disabilities

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ABSTRACT

By understanding how the brain receives messages from the eyes and vestibular system, upper extremity deficits that impair coordination in arms and hands can be overcome. This is accomplished when a person with type of disability closes his eyes to perform a specific task. Closing the eyes eliminates the messages the brain is receiving from them. Thus, the brain is only relying on information from the vestibular system. The theory put forth in this paper is: when information from the eyes is eliminated, upper extremity deficits are reduced.

If this notion is true, a person with upper extremity deficits can use this knowledge to have a more independent lifestyle, which will improve his quality of life by increasing educational and career opportunities.

To test this idea, thirteen people were asked to do seven basic tasks using wooden blocks. Each participant did all seven task twice. The first time a task was attempted, their eyes were opened and focused on the blocks. The second time, the participants had their eyes closed relying solely on information from his vestibular system to do the task. The time to complete each task and precision it was done with were measured and analyzed. The participants were also asked key demographic questions including questions about their education and employment histories.

OVERVIEW

People with disabilities like Cerebral Palsy or ALS, which often result in upper extremity deficits, can often improve their tactile accuracy and precision by understanding the mechanics of the vestibular system when performing tasks that are not automatic processes.

The organs of the vestibular system are located in the inner ear and have hair-like cells that send nerve impulses to the cerebellum to determine movement. The cerebellum in turn sends the same impulse to muscles so that they can move accordingly. The eyes also send messages to the brain about where a person is in their environment. If the cerebellum is damaged, gross and fine motor movement will not be well coordinated, which often causes the person's movement to be hampered.

This is particularly true when a person is looking at an object that they are trying to manipulate. Our observations demonstrate that when a person closes his eyes to perform a task, their movements will be less impaired and more precise. Closing the eyes eliminates the messages the brain is receiving from them. Thus, the brain is only relying on information from the vestibular system. Spasticity, tremors or any other type of upper extremity deficit no longer impedes the person's movement.

By eliminating upper extremity deficits, a person will be able to function more freely and independently. His quality of life may improve by receiving a higher education and obtain gainful employment because of this change.

Another explanation for the lack of upper extremity deficits is muscle memory. Muscle memory is the ability to perform movements or tasks identically, programming them into the subconscious mind so they can be recalled automatically from memory. Repetitions and mental focus are needed before a particular movement is committed to memory. Muscle memory is based upon the relationship between muscles, bones, and joints etc.

Athletes and musicians use muscle memory when they practice. A basketball player will practice a foul shot many times until it is perfect. In doing so, they have trained their muscles to shoot an accurate shot. It is now part of their muscle memory. Similarly, a musician will practice their instrument for hours so they can recall notes and chords effortlessly.

Muscle memory can be used to do daily activities as well. For example, when a person locks his door, he usually doesn't pay much attention to this activity. The process happens automatically or without conscious thought.

Muscle memory can also effect the movement of a person with a disability. When a person with a disability does a task repeatedly, they seem to have less deficiency in their movement whether their eyes are opened or closed.

METHODOLOGY

To examine the idea that closing eyes while doing a task eliminates upper extremity deficits, seven individuals who have disabilities that affects their upper body motor skills participated in an experiment. In addition to these participants, another six people who do not have any reported disabilities were tested to serve as a control group.

Each participant did two series of identical desktop tasks that involve manipulating wooden blocks. The first time the participants did the series, their eyes were opened and focused on the blocks. The second time, their eyes were shut.

These tasks are designed to test participants' gross and fine motor movement skills. Gross motor refers to the larger body movements and fine motor are the smaller ones. Some tasks will involve the arms-gross motor and some will use only the wrists and fingers-fine motor.

The hypotheses is that the tasks will be completed faster and with more precision when the participant's eyes are closed eliminating any upper extremity deficits.

Before the participants did the tasks, they answered a questionnaire intended to solicit basic demographic information.

DEMOGRAPHIC QUESTIONS

The following questionnaire was given to each participant.

- How old are you?
- What is your gender?
- What is your race?
- What is your marital status?
- Where do you live?
- What level of education have you completed?
- Do you have a disability? If so, what is your disability?
- How long have you had it?
- What is your main source of income?
- Are you employed?
- If so, what is your occupation?
- How long have you been working?

- Have you ever been employed?
- If so, what type of work?
- Why did it end?
- If you are not employed, what are the main reasons you do not work?
- If you are not employed, would you like to be?

After the participants answered these questions, they did the first series of tasks with the wooden blocks. The participants were given 120 seconds (2 minutes) to complete each task. Each individual task was timed with a stopwatch and scored for precision. These times and scores were recorded on a score sheet for further analysis.

At the beginning of each task, the researcher instructed the participant on what he must do to complete the task. For example, the researcher would say, "put one square block on top of the other." The participant was told that the test started when the researcher said "start". The participant was asked to say "finish" to indicate that he was done. The stopwatch began and ended timing with the words "start" and "finish" respectively. The amount of time it took for a participant to complete a task was then recorded on the score sheet along with a "precision score" which indicated how precisely the task was executed. The researcher determined the individual "precision score" at the completion of each task.

The time to do a task was measured in seconds. For instance, if it took a minute and ten seconds to finish a task, then the time recorded would be 70 seconds.

The "precision score" rated the degree of accuracy with which a task was completed. The possible "precision scores" were 0, 1, 2, or 3.

A "precision score" of "0" meant that the participant was unable to do the task in the 120 seconds he was given. Low precision meaning the participant barely completed the task will get a "1". A task that is done with moderate precision will get a "2" and "3" indicated the task was done with a high degree of accuracy.

The following is a description of the tasks that were performed by each participant.

Test	Purpose	Description
1.	Arm and Wrist Test	The participant will be given an array of 4 long, thin rectangles that have a square shape at the end. The participant will line up the square shape ends.
2.	Wrist and Fingers	The participant will be given 2 rectangles and asked to put one on top of

		the other.
3.	Wrist and Fingers	The participant will be given 1 wide rectangle and 2 squares and then asked to put the 2 squares on top of the rectangle.
4.	Wrist and Fingers	The participant will be given 3 squares and then asked to pile one on top of the other.
5.	Wrist and Fingers	The participant will be given 2 semi-circles and then asked to put them together to form a whole circle.
6.	Wrist and Fingers	The circle from the previous task will remain in front of the participant. The participant will then be given 2 arches and will place the curved side of each arch around the circle forming a square.
7.	Arms, wrists and fingers	There will be an array of 10 different shapes and a box in front of the participant. The participant will be asked to put each shape in the box.

After the participants completed all 7 tasks, they were instructed to do them again. The same rules apply about when the tasks begin and end. The time it took to finish each task and its "precision score" were recorded again.

The major difference between the first time a participant did the series and the second time is that he closed his eyes for the second attempt.

If the hypothesis is correct, a participant will do the tasks on the second attempt quicker than the first and have a higher "precision score". The reason is that the participant’s cerebellum is solely relying on information from the vestibular system and not his eyes. As stated before, when information from the eyes is eliminated, upper extremity deficits are reduced.

DISCUSSION

The typical female participant was white with cerebral palsy who didn't work and collects Supplemental Security Income (SSI) as her primary income source. For men, the typical participant was white and had never been married.

There were 13 participants in all. Nine were women and 4 were men. Five women and 2 men had disabilities that effected movement in their upper body specifically in their arms, hands, wrists and fingers. The average age of this population was 43.9-years-old and the median age was 42-years-old.

Out of the 13 participants, 6 said that they completed college or had some experience with college. Three of them were disabled. Six participants had a high school level education. Half of them had disabilities. The one remaining participant was disabled and had no reported education.

The 2 most common income sources identified were SSI and a salary. All 4 of the participants who used SSI exclusively for income were disabled. Another 4 said a salary was their means of income were all able-bodied. The 5 remaining participants named other sources or a combination of sources as their income.

Testing usually occurred at Liberty Resources, Inc., a Center for Independent Living in Philadelphia.

The duration of the entire test was varied depending on ability. For those having disabilities, the testing lasted approximately 35-45 minutes. Able-bodied participants took about 15-20 minutes to complete the testing.

On the whole, most participants had a positive attitude towards the testing. Many of them were amused at doing tasks with their eyes closed. The participants were given encouragement as they went through the test, especially if they seemed to be getting frustrated. One participant after completing a few tasks said that it was "stupid".

As stated earlier, precision scores were designed to measure the precision or accuracy with which a task was completed. They ranged from 3 to 0. A score of 3 meant a task was done with perfect precision. The precision score decreased as the precision lessened. A 0 score meant that the participant was unable to do the task in the time allotted.

Precision scores can be analyzed in numerous ways using the information generated from the demographics questions.

ANALYSIS BASED ON GENDER

Starting with gender: In the first round, the 9 female participants had 57 out of 63 precision scores were 3's. Then, for the second round, precision declined for the women as only 52 scores were a 2 or 3. The remaining lower scores occurring in the second round all came from females who had disabilities. All of these scores appeared in tasks where arm movement, arranging or stacking blocks were required to complete the task.

Disabled participants having difficulty in the second round (eyes closed) with tasks using arm movement, arranging and stacking blocks is a trend that is seen throughout the analysis of precision scores.

For the men, they had 25 out of 28 scores that were 2's and 3's in the first round, while only 19 scores were either a 2 or 3. Similar to the female group, all of the lower scores in the second round came from men with disabilities.

ANALYSIS BASED ON DISABILITY

A comparison of precision scores can be made between participants who have upper extremity deficits and those who do not. For the ones with disabilities, 42 out of 49 precision scores were 3's for the first round eyes open). In the second round (eyes closed), precision tended to decrease as only 29 scores were 2's or 3's. The 0's and 1's from this round occurred more often in tasks where arm movement, arranging or stacking blocks was required.

Able-bodied participants had 38 out of 42 precision scores that were rated as 3 for the first round. In the second round, the number of 3's went down slightly as only 36 were scored a 3 for this same group.

ANALYSIS BASED ON AGE

Precision scores can also be examined in terms of ages of participants. Five of the participants were younger than the median age of 42. From this group, 3 had disabilities. Young, disabled participants had 20 out of 21 precision scores that were 2's or 3's in the first round (eyes open). Precision decreased in the second round (eyes closed) for this population as there were only 14 scores that were either 2's or 3's. The remaining scores that were lower than 2 typically occurred in tasks that required arm movement or arranging blocks in a certain pattern.

The 2 younger participants who didn't have disabilities did very well with precision. All precision scores in the first round were 3's and 11 out of 14 were 3's in second round.

Out of 8 participants who were 42 years of age or older, half had disabilities. The older group with disabilities scored a 3 on 26 out of 28 precision scores in the first round (eyes open). Precision wasn't quite so high in the second round (eyes closed). Only 15 were 2's or 3's for this round. The lower precision scores

appeared again in tasks that had to do with arm movement, arranging and piling blocks.

ANALYSIS BASED ON EMPLOYMENT STATUS

Precision scores can be further analyzed by looking at the participants who were employed and those who were not. The 6 participants who considered themselves employed scored 39 3's out of 42 scores in the first round and in the next round 38 were either 2 or 3.

For the 7 participants who weren't working, 47 out of 49 of their precision scores were either a 2 or 3 in the beginning round (eyes open). Precision dropped in the second round (eyes closed) as only 34 scores were a 2 or 3.

The information on employment can be broken down even further by factoring the disability variable.

The 2 participants who identified themselves as being employed and disabled had in the first round 13 out of 14 3's. Precision dropped in the second round, as only 10 of their precision scores were a 2 or 3.

For the unemployed and disabled group of participants, they scored 33 out of 35 precision scores of a 2 or 3 in the first round (eyes open). For the second round (eyes closed), 16 scores were either a 0 or a 1. Again, these lower scores happened mostly in tasks where arm movement or arranging blocks in a specific pattern was needed to finish the task.

The able-bodied participants who worked did very well with precision. This group had 26 out of 28 scores that were rated a 3 for both rounds.

ANALYSIS BASED ON INCOME SOURCE

The group using SSI had 26 out of 28 precision scores that were either 2 or 3 in the first round. In the second round, there were only 17 2's and 3's for this group. Once again, the lower scores in the second round occurred in tasks where arm movement, arranging or piling blocks was involved.

For the 4 participants who said a salary is their income source, 26 out of 28 precision scores were 3's for both rounds. All 4 participants in this group were able-bodied.

ANALYSIS BASED ON COLLEGE EDUCATION

Having a college degree or at least some college education can be another factor determining how a person will perform on a precision test. The 6 participants with college experience had 39 out of 42 scores that were 3's in the first round (eyes open). Precision then dropped in the second round as 35 scores were either a 2 or 3 for this same group.

There were 7 participants who had absolutely no experience with college. They scored 47 out of 49 were 2's or 3's in the first round (eyes open). For the second round (eyes closed), only 35 were ranked as a 2 or 3.

The education variable can also be studied in terms of college education factored in with disability. The 3 disabled participants with college experience had 20 3's out of 21 precision scores in the first round and in the second round 14 of the scores were either a 2 or 3.

For the 4 participant who were disabled and had no college education, 26 out of 28 scores were a 3 or 2 in the first round. Precision fell off substantially in the second round as only 15 scores were rated that high. The lower scores from this round were scattered throughout the various tasks.

The 3 college educated participants without disabilities had 18 out of 21 precision scores were either a 2 or 3 in the first round. Precision improved for this group as there were 18 3's in the second round.

Those having no disability and no college education, 3 participants in all, had 18 3's out of 21 for both rounds.

RESULTS - Precision Score Matrix

Eyes open

Test #	Young Non-disabled Salary	Young Disabled SSI	Old Non-disabled Salary	Old Disabled SSI
1	3.0	2.5	3.0	3.0
2	3.0	2.0	3.0	3.0
3	3.0	3.0	2.0	3.0
4	3.0	3.0	3.0	1.5
5	3.0	2.5	2.0	3.0
6	3.0	3.0	3.0	3.0
7	3.0	1.5	3.0	2.5

Table 1 Precision score averages for the first round

Eyes closed

Test	Young Non-disabled Salary	Young Disable SSI	Old Non-disable Salary	Old Disabled SSI
1	3.0	1.0	3.0	1.0
2	3.0	1.5	3.0	2.0
3	2.5	2.5	3.0	3.0
4	2.5	2.5	3.0	0.0
5	2.5	3.0	3.0	2.0
6	3.0	1.0	3.0	3.0
7	3.0	1.5	3.0	1.5

Table 2 Precision score averages for the second round.

In the above tables, the participants are divided into 4 groups and the average precision score for the groups is listed according to each task. There were 5 participants whose results weren't calculated in the above findings because their reported income source wasn't a salary or SSI.

The results demonstrate that precision decreased for most of the groups when they closed their eyes in the second round. The only exception was the older, non-disabled group whose precision went from nearly perfect to perfect. Combining the 2 disabled groups and the 2 non-disabled groups, it is shown that the non-disabled participants did better with precision since their scores didn't fall off as much as the ones with upper extremity deficits.

CONCLUSION

Precision decreased when participants closed their eyes in the second round. However, precision dropped more dramatically for the participants who were disabled than it did for the ones who were able-bodied. The only exception was the older, non-disabled group who increased their precision in the latter round (eyes closed). This analysis leads to the conclusion that the able-bodied participants did better with precision than their disabled counterparts.

One explanation for the increase in the second round for the older, able-bodied group is muscle memory. These participants used the first attempt at the tasks as a practice session. During the practice sessions, the participants learned how to do the tasks so the second time around they did them with higher proficiency.

It is interesting to note that the group that did the poorest with precision was the disabled participants with no college education. All 4 participants who fall into this category have 2 significant things in common: None of them are employed and they are all on some type of Social Security Insurance. This may lead to the

conclusion having upper extremity deficits may effect the level of education a person reaches, which, in turn, will effect his employment status in the future.

Since able-bodied adults are more likely to be better educated and earn a salary, it can be concluded based on these results that the ability to perform tasks that require precision will predict whether a person will be employed and earning a livable wage.

Unfortunately, in the past, those who did not have this capability – people with upper extremity deficits – were not well educated, did not work and depended on government programs for income. All of these variables, along with many others, influence a person's quality of life. The quality of life for people with upper extremity deficits or any other disabilities often suffered because of these factors were missing in their lives.

To fully understand quality of life issues faced by people with disabilities, more studies are needed that look at institutionalization, discrimination and other barriers that effect the lives of people with disabilities.

Also, additional research on the role of muscle memory on upper extremity deficits would be beneficial to the disability community. This research would focus on doing tasks repeatedly – does it decrease the effects of the upper extremity deficits? If so, persons with upper extremity deficits can use this information to better their lives.

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