HOW BALANCE ALTERS VISUAL SYSTEM PERFORMANCE

by

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This paper is submitted in partial fulfillment of the
requirements for the degree of

Doctor of Optometry

Ferris State University
Michigan College of Optometry
May 2010

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Has been approved

May 2011

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Ferris State University
Doctor of Optometry Paper
Approval and Release

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4/28/2011

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4/28/2011

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ABSTRACT

Background: This experimental study will examine how balance affects performance of the visual system in young children. *Methods*: Three Head-Start programs located in Tustin, Evart, and Reed City, MI participated in the study. At each program 20-25 children aged 3-5 years old participated in a series of three tests (Bell retinoscopy, NSUCO oculomotor test, and near point of convergence) to determine a baseline for visual system performance in accommodative posture, tracking ability, and convergence amplitude respectively. The same tests were repeated while the child is sat on a balance ball. Children were randomly selected to either complete the tests first while sitting on the balance ball or while standing in order to minimize learning effects. *Results*: Data obtained from the tests were analyzed using multiple statistical measures (i.e. t-test, ANOVA etc.) to determine if there is a relationship between the performance of the visual system and balance. Qualitative observations were also noted. *Conclusions:* The data suggests that the accommodative and convergence systems are unaffected when actively balancing, but the ability to make effective saccades is compromised.

ACKNOWLEDMENTS: We would like to recognize Dr. Sarah Hinkley for being our project advisor and providing helpful advice and instruction. We would also like to thank NEMCSA Head Start program and the teachers involved with this study, especially Jesusita Brinker for all of her help getting the teachers and parents on board with this research project. And lastly thank you to all of the parents who allowed their children to be a part of this project to the children who participated and did such an amazing job.

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INTRODUCTION:

The purpose of the study was to examine any correlation between balance and performance of the visual system of young children. The areas of the visual system studied were accommodative lag, near point of convergence, and extra-ocular muscle function. We speculated that because of the close neurological proximity and connections between the vestibular system and brain portions controlling the three areas of the ocular system that were tested that there would be some affect on the visual system when a child had to concentrate on balancing.

Accommodation is controlled by the Edinger-Westphal nucleus, which is located in the rostral midbrain at the level of the superior colliculus. Convergence is shown to be controlled by a few different parts of the brain including the frontal and posterior cortex and floccular region and cerebellar nuclei in the cerebellum. Smooth pursuit eye movements involve several areas of the brain. These areas include the visual cortex, parietal cortex, and the frontal eye field and supplementary eye field in the frontal cortex.[1] Labrinthine receptors in the inner ear are associated with hearing and equilibrium. These receptors play an important role in integrating eye movements with balance. The pathways of these receptors take two separate paths to the extra-ocular muscles; the first is via a three neuronal arc that traverses mainly through the medial longitudinal fasciculus (MLF). The second pathway involves a complex multi-synaptic route through the reticular formation that may take a direct route and/or run through the MLF as well. The three neuronal arc connects the receptors of the inner ear to the extra-ocular muscles by the primary vestibular neuron, the secondary vestibular neuron, and motor neurons of the cranial nuclei responsible for innervating the six extra-ocular muscles.[2]

We hypothesized that there would be a statistically significant difference in at least one of the areas tested between measurements taken while the child is standing and while the child was seated on a balance ball.

METHODS:

51 three to five year old Head Start students participated in the study. These students were from the Reed City, Tustin, or Evart, MI Head Start locations. A letter was sent to the administrators of the Head start program to gain permission to perform the study on the Head Start Program students in their area (see appendix A).The same letter format was sent to the teachers of all the classrooms (see appendix A). Upon receiving teacher permission letters explaining the study were sent to the teachers to distribute to the parents/legal guardians (see appendix B) as well as parent/guardian permission forms that allowed performance of the three tests on their children (see Appendix C).

To protect the privacy of the children who participated in this research project we used a numbering system while collecting the data (Table 2). We collected all the data on forms created for this experiment (see Appendix D). All of our data was then put into tables for further analysis (Tables 2, 3, 4).

One of the tests performed on each subject was bell retinoscopy to measure each child's accommodative lag. This allowed us to know where the subject was focusing relative to the target. Bell retinoscopy is a procedure that is preformed with the examiner at a constant 50 centimeters while using a fixation target that is moved toward the patient while observing the retinoscopy reflex. Typically there are two measurements recorded with Bell retinoscopy. The first measurement is the distance of the fixation target from the patient when the reflex changes from "with motion" to "against motion" and the second measurement is when the reflex changes from "against motion" to "withmotion".[3]The point was recorded where the motion appeared to be neutral since it was difficult to keep the child's visual attention for long periods of time. The normal accommodative lag is between 14 inches and 18 inches.[3] Near point of convergence was also performed. This test quantifies the subjects' ability to converge their eyes while maintaining fusion. Near point of convergence was tested by having the patient keep their eyes focused on a specific target—a small pencil top toy—and while instructed to keep the object clear (in focus). Colorful finger puppets were used as the targets. Participants were asked to report when the target became double. The next step was pulling the target further away from the patient and measuring when the patient reported single vision indicating fusion wasregained.[3] Because of the age and reliability of the subjects in this study, measurement were recorded based on observation alone when subjective response was not reliable. Objective response was recorded by observing when the child lost fusion of the near point target, indicated by when one eye turned away from fixation. Using observation to collect the near point of convergence made it difficult to find an accurate recovery, therefore in the end that measurement was omitted. The near point of convergence was measured in centimeters. The normal value for near point of convergence is less than 5 centimeters.[4]The final test preformed was NSUCO (Northeastern State University College of Optometry) oculomotor test to assess the quality and accuracy of saccadic and pursuit eye movements. NSUCO was administered with the patient standing with feet shoulder-width apart.[5] The targets were to be held no less than Harmon's distance (distance from elbow to middle knuckle) and no more than 40cm away from the eyes.[6] Colored finger puppets were utilized to help keep the subjects' attention. To examine saccades the subjects were instructed to look at one of the targets and then the second target when instructed. The targets used were the same as the targets used in the previous tests. The targets for saccadic measurements were to be held no more than 10 cm from the midline on each side. To examine pursuits the subjects were instructed to watch the target as it went around and not to take their eyes off the target.[6] Each child was scored using the guidelines in Table 1.

The normal values used for saccade testing with NSUCO for 5 year olds were as follows: head movements needed to score at least"2" regardless of sex, body movement had to score at least"3" for males and "4" for females, accuracy had to score at least "3" regardless of sex, and ability had to be at least "5" regardless of sex.[5] The normal values used for pursuit testing for 5 year olds was as follows: head movement had to score at least "2" for males and"3" for females, body movement needed to score at least "3" for males and "4" for females, accuracy needed to score at least "2" for males and "3" for females and ability needed to score at least "4" for males and 5 for females.[5] The three tests were performed on each child twice, once while they were standing and once while they were sitting on a large balance ball. Children were randomly selected as to which would perform the tests while standing first and which children would perform the tests while sitting on the balance ball first in order to minimize the learning effects.

RESULTS:

Since some of the children were not able to complete a few of the tasks, those tests were omitted when applying statistical tests. When performing near point of convergence, 0 was used in statistical analysis when TTN (to the nose) was recorded. To compare the means between the experimental group and the control group, a student-t test was performed. By using a two-tailed student t-test the relationship between the two sets of data could be compared in both directions.[7] For example, if an experimental group mean was tested against a control group mean, the two-tailed test would evaluate if the mean of the experimental group was significantly greater than or less than the mean of the control group. Lastly, unequal variances were used because of the difference in sample size with some tests omitted for children unable to complete the task.

There was a statistically significant difference between the experimental and control group on a few of the tests. Any value of p less than or equal to 0.05 is considered to be statistically significant from the control, or standing group:

Bell Retinoscopy:

OD: p-value=0.337, p<=0.05

OS: p-value=0.433, p<=0.05

NPC: p-value=0.577, p<=0.05

Pursuits:

HB: p-value=0.541, p<=0.05

AB: p-value=0.022, p<=0.05

AC: p-value=0.006, p<=0.05

Saccades:

HB: p-value=0.001, p<=0.05

AB: p-value=0.213, p<=0.05

AC: p-value=0.005, p<=0.05

In order to test for a statistically significant difference in visual system performance between sitting and standing, a null and alternative hypothesis was formed:

H_0: There is no statistically significant difference between visual performance standing and visual performance sitting on a balance ball.

H_A: There is a statistically significant difference between visual performance standing and visual performance sitting on a balance ball.

For all values of p<=0.05 the null hypothesis must be rejected and the alternative hypothesis can be accepted. All statistical data can be found in Table 5.

DISCUSSION:

The data suggests that the accommodative and convergence systems were unaffected when actively balancing, but the ability to track and effectively make saccades were affected. Stabilization of gaze involves many different groups of muscles and sensory systems working in harmony. Of the numerous systems, the vestibular system may be one of the most important extra-retinal components. A recent study between the interactions of extra-retinal, vestibular and visual mechanism's role in gaze control during head-free pursuit showed that the vestibulo-ocular response (VOR) remained and relies on extra-retinal systems to counteract the VOR.[8] Furthermore, head motion during head-free pursuit was reported to be controlled solely by internal mechanisms without direct input from visual feedback. Because of the close link between head movements, stabilization of gaze and visual stimuli, it is possible to infer that adding a stress to the vestibular system could cause a cascade that would lead to decreased accuracy of eye movements. It is possible that activation of the vestibular system during active balancing could detract neurological stimulation from processes connecting vestibular control to saccades or pursuits.

The results showed pursuit ability and accuracy were impaired while head and body movements were not. During the VOR the eyes are turned in the opposite direction of head turn. Extra-retinal processes and visual stimuli countermand the VOR to keep the gaze in the direction of the target in motion.[9]The stresses of keeping the head stable during active balancing coupled with body sway and the lack of grounded objects to stabilize visual posture can cause the visual system to break down leading to a decreased ability and accuracy during the test.[10]

The results showed that saccadic testing ability was unaffected by active balancing, while head and body movements and accuracy were impaired. Initialization of a saccade is a voluntary procedure that only requires an attentional target to make the eye movement occur. Since this sequence does not require input of the vestibular system, balance should have no impact on the ability to initiate saccades. The data gathered supports this theory. Saccades are generated in a specific area of the superior colliculus and the frontal eye fields. The superior colliculus also has neurons that respond to auditory and somatic stimuli.[11] It is interesting to note that during the act of a saccade the

VOR is suppressed for the duration of the saccade.[12] Accuracy of saccadic movements is tied to the position of the object, involvement of the vestibular system and the position of the body in space. Any stresses on the vestibular system, such as balancing on a balance ball and the somatic nervous system could have a direct effect on the accuracy of the saccadic eye movements. As the accuracy of eye movement decreases, the body and head compensate by turning toward the target to minimize the amplitude of subsequent saccades to reach the target.[13, 14] This would account for the large discrepancy between head and body movement and accuracy of saccades while sitting on a balance ball compared to standing.

LIMITATIONS: The procedures executed in this research were performed objectively because of the reliability and age of the subjects tested, causing the potential for errors in the collection of the data. Therefore further information could be gleaned from extended testing actively stressing the vestibular system in adults since the reliability factor increases significantly in adults. Even with the potential of some error through objective testing, the trends shown in the statistical analysis should not be discounted since subjective observation of the examiners closely matched the final data, including the children struggling with certain aspects of the tests when having to concentrate on staying balanced, especially during pursuits and saccades.

A larger study population with more population diversity would have provided additional data to support or refute current results.

CONCLUSION:

This research supports a strong connection between active balancing and effects on the visual system, particularly in regards to pursuit ability and accuracy and saccade accuracy and coinciding head and body movement. Results support strong and healthy integration between the vestibular, visual and oculomotor systems in preschool children.

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APPENDIX A

TEACHER/ADMINISTRATOR STUDY DESCRIPTION LETTER

TEACHER/ADMINISTRATOR STUDY DESCRIPTION LETTER

February 10, 2010

Dear Mrs. ____________,

Our names are Sarah Hinkley, OD, FCOVD, Amber Bowen and Brian Hales. We are students and a faculty member at the Michigan College of Optometry located in Big Rapids, MI. For our Senior Research Project we would like to conduct a study on how the visual system is affected by balance. We are inquiring about if it would be possible to conduct our study in your classroom. We expect to need about 10 minutes per child and can accommodate your classroom schedule.

The purpose of this study is to find out if there is a direct relationship between balance and the visual system. This study would require us to do three observational procedures on each child first standing and then repeated while sitting on a balance ball. These procedures are quick, non-invasive, routine tests administered in eye care provider offices across the country and pose no risk of harm. No identifying information will be recorded and only a random number, age and gender will be recorded for each child. If you agree, parents/legal guardians will be sent home a study description and permission slip to be returned if consent is granted for study participation. Only those with permission granted will be utilized in our study.

Testing your students for our study would be beneficial to our learning experience and contribute to our research on the visual system. The knowledge gained may be useful for optimizing educational techniques and better understanding how the visual system relates to the vestibular (balance) system of a child. You have the right to refuse participation.

Thank you very much for considering our request. Please contact us or our project advisor, Sarah Hinkley, OD, FCOVD, 231-591-2185 with any questions or concerns.

Sincerely,

Sarah Hinkley, OD, FCOVD	Amber Bowen	Brian Hales
231-591-2185	231-679-5973	989-506-7137
sarahhinkley@ferris.edu	bowen.amberl@gmail.com	hales1bm@gmail.com

APPENDIX B

PARENT/LEGAL GUARDIAN STUDY DESCRIPTION LETTER

PARENT/LEGAL GUARDIAN STUDY DESCRIPTION LETTER

February 10, 2010

Dear Head-Start Parent or Legal Guardian,

Our names are Sarah Hinkley, OD, FCOVD, Amber Bowen and Brian Hales. We are students and a faculty member at the Michigan College of Optometry at Ferris State University located in Big Rapids, MI. For our Senior Research Project we will be conducting a study on how the visual system is affected by balance. We are inquiring about if it would be possible to conduct our study on your child in his/her Head-Start classroom. We expect to need about 10 minutes with your child.

The purpose of this study is to find out if there is a direct relationship between balance and the visual system. This study would require us to do three observational procedures on your child first standing and then repeated while sitting on a balance ball. These procedures are quick, non-invasive, routine tests administered in eye care provider offices across the country and pose no risk of harm. No identifying information will be recorded and only a random number, age and gender will be recorded for each child. You have the right to refuse participation. Please return the permission slip stating whether you consent to study participation by your child. Only those with permission granted will be utilized in our study. If for any reason your child does not want to participate during the course of this study he or she can return to their normal classroom activities at any time.

Testing your child for our study would be beneficial to our learning experience and contribute to our research on the visual system. The knowledge gained may be useful for optimizing educational techniques and better understanding how the visual system relates to the vestibular (balance) system of a child.

Thank you very much for considering our request. Please contact us or our project advisor, Sarah Hinkley, OD, FCOVD, 231-591-2185 with any questions or concerns.

Sincerely,

Sarah Hinkley, OD, FCOVD
231-591-2185
sarahhinkley@ferris.edu

Amber Bowen
231-679-5973
bowen.amberl@gmail.com

Brian Hales
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APPENDIX C

PARENT/LEGAL GUARDIAN PERMISSION SLIP

PARENT/LEGAL GUARDIAN PERMISSION SLIP

How Balance Alters Performance of the Visual System Research Project

Please sign the form below indicating whether your child may participate in our study on balance and the visual system and return it to your child's Head-Start program within one week of receiving this letter.

I prefer that my child, ____(child's name)

________does

________does not

participate in your study on balance and the visual system. I understand that it is my right to accept or decline this offer for voluntary participation and that my child also has the right to refuse participation at any point without penalty. I understand that participation is confidential and anonymous and any questions can be addressed to Sarah Hinkley, OD, FCOVD at 231-591-2185. I acknowledge that there are no risks of injury or associated costs.

Parent or Legal Guardian's
Signature:____

Date: ________________________________

APPENDIX D

SENIOR RESEARCH PROJECT REPORTING FORM

SENIOR RESEARCH PROJECT REPORTING FORM

STANDING: 1st___ 2nd___

Date:_______________ Subject #_________________

Age:_________ Gender: M F

Bell Ret: OD:_______________OS:________________

NPC: TTN or ___________cm

NSUCO-saccades:	Head/Body Movements:	1	2	3	4	5
	Ability:	1	2	3	4	5
	Accuracy:	1	2	3	4	5
NSUCO-pursuits:	Head/Body Movements:	1	2	3	4	5
	Ability:	1	2	3	4	5
	Accuracy:	1	2	3	4	5

BALANCE BALL: 1st____ 2nd____

Date:_______________ Subject #_________________

Age:_________ Gender: M F

Bell Ret: OD:_______________OS:________________

NPC: TTN or ___________cm

NSUCO-saccades:	Head/Body Movements:	1	2	3	4	5
	Ability:	1	2	3	4	5
	Accuracy:	1	2	3	4	5
NSUCO-pursuits:	Head/Body Movements:	1	2	3	4	5
	Ability:	1	2	3	4	5
	Accuracy:	1	2	3	4	5

TABLE 1

NSUCO SCORING CRITERIA

NSUCO SCORING CRITERIA

NSUCO SCORING CRITERIA			
Saccadic Eye Movements	Head and Body Movement:	1	large movement of head or body at any time
		2	moderate movement of head or body at any time
		3	Slight movement of head or body (>50% of the time)
		4	Slight movement of head or body (<50% of the time)
		5	No movement of head or body
	Ability:	1	Completes less than 2 round trips
		2	Completes 2 round trips
		3	Completes 3 round trips
		4	Completes 4 round trips
		5	Completes 5 round trips
	Accuracy:	1	Large over/undershooting is noted 1 or more times
		2	moderate over/undershooting noted 1 or more times
		3	constant slight over/undershooting noted (>50% of time)
		4	intermittent slight over/undershooting noted (<50% of time)
		5	no over/undershooting noted
Pursuit Eye Movements:	Head and Body Movement:	1	large movement of head or body at any time
		2	moderate movement of head or body at any time
		3	Slight movement of head or body (>50% of the time)
		4	Slight movement of head or body (<50% of the time)
		5	No movement of head or body
	Ability:	1	cannot complete ½ rotation in either direction
		2	Completes ½ rotations either way
		3	Completes 1 rotation either way
		4	Completes 2 rotations in 1 direction but <2 rotations in other direction
		5	Completes 2 rotations in both directions
	Accuracy:	1	no attempts to follow or >10 refixations
		2	refixates 5-10 times
		3	3-4 refixations
		4	2 or less refixations
		5	no refixations

TABLE 2

SUBJECT NUMERS DATA

SUBJECT NUMBERS DATA

Subject Number Data				
Subject	Age	Sex	Location	Sit or Stand 1st
1	4	F	RC-PM	Stand
2	4	M	RC-PM	Sit
3	4	F	RC-PM	Stand
4	4	F	RC-PM	Sit
5	4	M	RC-PM	Sit
6	4	M	RC-PM	Stand
7	4	M	RC-PM	Stand
8	4	F	RC-PM	Sit
9	4	F	RC-PM	Sit
10	4	F	RC-PM	Sit
11	5	M	RC-PM	Sit
12	4	F	RC-PM	Sit
1	4	M	RC-AM	Stand
2	4	F	RC-AM	Stand
3	4	F	RC-AM	Sit
4	4	F	RC-AM	Stand
5	3	F	RC-AM	Stand
6	4	F	RC-AM	Stand
7	4	M	RC-AM	Stand
8	4	F	RC-AM	Stand
9	4	M	RC-AM	Stand
10	4	M	RC-AM	Stand
11	4	F	RC-AM	Stand
12	4	M	RC-AM	Stand
13	4	F	RC-AM	Stand
14	4	F	RC-AM	Stand
1	3	F	Tustin	Stand
2	4	M	Tustin	Stand
3	4	F	Tustin	Stand
4	3	F	Tustin	Stand
5	4	F	Tustin	Sit
6	4	F	Tustin	Stand
7	3	M	Tustin	Stand
8	4	F	Tustin	Stand
9	4	M	Tustin	Stand
10	4	M	Tustin	Sit
11	3	F	Tustin	Stand
12	3	F	Tustin	Sit
13	3	M	Tustin	Stand
14	4	F	Tustin	Stand
15	4	M	Tustin	Stand

1	4	M	Evart	Stand
2	4	M	Evart	Stand
3	5	F	Evart	Stand
4	3	F	Evart	Stand
5	3	F	Evart	Sit
6	4	M	Evart	Stand
7	4	M	Evart	Sit
8	4	F	Evart	Stand
9	4	M	Evart	Sit
10	3	M	Evart	Sit

TABLE 3

STANDING DATA

STANDING DATA

Patient Number	Standing Data								
	Bell		NPC	NSUCO					
	OD	OS		pursuits HB	pursuits AB	Pursuits AC	Saccades HB	Saccades AB	Saccades AC
1	20	20	6	2	4	4	4	4	4
2	24	24	4	4	4	4	4	4	4
3	20	20	2	4	2	3	4	4	3
4	22	22	TTN	4	4	4	4	4	4
5	24	24	2	3	3	3	4	3	3
6	19	19	5	4	3	4	4	4	4
7	21	21	4	3	4	3	3	4	4
8	19	19	3	4	3	4	4	4	4
9	20	24	5	4	3	3	4	4	3
10	24	24	TTN	4	3	3	3	4	4
11	20	22	5	4	3	3	4	4	3
12	20	20	TTN	4	3	3	4	4	3
13	24	24	TTN	3	4	3	4	5	4
14	20	23	5	2	2	2	4	3	3
15	10	10	3	3	3	3	4	3	3
16	12	12	5	4	4	4	4	4	4
17	15	15	2	5	4	4	4	4	4
18	19	19	TTN	2	4	4	3	4	4
19	11	11	2	3	3	3	3	4	4
20	20	20	4	4	5	4	5	5	5
21	20	22	TTN	3	4	4	4	4	4
22	20	22	TTN	3	4	4	4	4	4
23	15	15	4	3	4	3	4	3	3
24	17	17	TTN	4	4	3	4	5	4
25	20	20	1	5	4	3	5	4	4
26	17	17	5	4	3	2	4	4	3
27	20	20	2	4	3	4	4	4	3
28	17	17	2	3	3	2	2	4	3
29	18	18	2	5	4	4	4	4	4
30	27	28	3	4	3	3	4	4	3
31	17	17	5	4	3	3	4	4	4
32	22	22	4	3	2	3	4	4	4
33	17	17	TTN	5	4	4	5	3	3
34	16	18	4	5	4	4	4	4	4
35	22	22	TTN	4	4	3	4	4	4
36	26	26	TTN	4	2	2	4	4	4
37	19	19	TTN	3	2	2	3	4	4
38	17	17	3	2	2	2	3	3	3
39	18	18	TTN	3	3	3	4	4	4
40	26	26	3	4	4	3	4	4	4
41	24	24	5	4	4	4	4	4	4
42	21	21	2	4	4	4	4	4	4
43	20	20	5	2	2	2	3	3	3

44	18	18	4	4	3	3	3	4	4
45	30	30	4	4	4	4	5	4	4
46	17	17	TTN	3	2	2	3	2	2
47	19	19	TTN	4	4	4	5	4	4
48	23	23	2	5	4	3	5	4	4
49	20	20	5	4	2	2	4	4	4
50	20	20	TTN	2	2	2	3	4	3
51	17	17	3	4	3	4	4	3	4

TABLE 4

SITTING DATA

SITTING DATA

Subject Number	Sitting Data								
	Bell		NPC	NSUCO					
	OD	OS		pursuits HB	pursuits AB	Pursuits AC	Saccades HB	Saccades AB	Saccades AC
1	25	25	5	4	3	3	3	4	4
2	24	24	4	4	4	4	4	4	4
3	19	19	2	3	2	2	3	3	3
4	18	18	TTN	4	4	4	4	4	4
5	28	28	2	3	3	3	3	4	3
6	21	21	5	2	4	4	3	4	4
7	19	19	2	3	3	3	3	3	3
8	24	24	2	4	3	3	4	4	3
9	28	32	3	4	3	2	3	3	3
10	20	20	TTN	3	3	3	3	4	3
11	25	25	5	3	2	2	3	3	3
12	20	20	1	4	2	2	4	3	3
1	30	30	TTN	3	4	3	4	5	4
2	18	18	4	2	2	2	4	4	3
3	20	22	3	4	5	4	4	5	4
4	25	25	5	3	3	4	3	3	3
5	10	10	2	5	5	4	3	4	2
6	18	18	TTN	5	4	3	2	4	4
7	7	7	3	1	1	1	NA	NA	NA
8	24	24	5	4	5	4	4	4	4
9	20	22	TTN	3	3	3	3	4	3
10	20	22	TTN	3	3	3	3	4	3
11	18	18	2	4	2	2	2	4	4
12	21	21	TTN	4	5	4	4	4	3
13	20	20	2	4	2	2	4	4	4
14	18	18	3	4	2	2	4	4	3
1	20	20	2	4	2	2	3	4	4
2	18	18	2	3	2	2	3	4	2
3	17	17	2	5	4	4	4	4	4
4	20	21	3	4	3	3	5	4	4
5	19	19	5	5	4	4	4	4	4
6	16	16	5	3	2	2	3	3	2
7	19	19	2	2	2	2	4	4	3
8	18	20	4	4	4	3	4	4	3
9	20	20	TTN	4	3	3	4	4	4
10	20	20	TTN	5	1	1	4	3	3
11	17	17	1	3	2	2	3	4	4
12	19	19	3	3	2	2	3	2	2
13	22	22	TTN	2	1	2	3	3	3
14	19	19	3	4	4	4	4	4	4
15	NA	NA	Na	Na	Na	Na	NA	NA	NA
1	19	19	5	4	3	2	4	4	3

2	24	24	2	2	2	2	2	2	2
3	22	22	3	3	2	2	3	4	4
4	25	25	TTN	3	3	3	3	4	3
5	19	19	TTN	3	2	2	3	2	2
6	28	28	TTN	4	3	3	3	4	4
7	19	19	3	5	2	2	5	4	4
8	19	19	5	4	3	2	4	4	4
9	22	22	TTN	3	2	3	1	4	3
10	18	18	2	4	3	4	4	3	3

TABLE 5

STATISTICAL DATA

STATISTICAL DATA

STANDING

	BELL			NSUCO
	OD	OS	NPC	Pursuits HB
Average	19.69	20.00	2.45	3.63
Standard Deviation	3.79	3.91	1.99	0.85
Sample Size	51	51	51	51
Confidence Interval (95%)	1.04	1.07	0.55	0.23
Confidence Interval Mean High	20.73	21.07	3.00	3.86
Confidence Interval Mean Low	18.65	18.93	1.90	3.39
p-value	0.377	0.433	0.577	0.541

NSUCO				
Pursuits AB	Pursuits AC	Saccades HB	Saccades AB	Saccades AC
3.29	3.20	3.88	3.86	3.67
0.81	0.75	0.62	0.53	0.55
51	51	51	51	51
0.22	0.21	0.17	0.15	0.15
3.52	3.40	4.05	4.01	3.82
3.07	2.99	3.71	3.72	3.51
0.022	0.006	0.001	0.213	0.005

SITTING

BELL			NSUCO
OD	OS	NPC	Pursuits HB
20.38	20.64	2.24	3.52
4.06	4.25	1.79	0.91
50	50	50	51
1.13	1.18	0.50	0.25
21.51	21.82	2.74	3.77
19.25	19.46	1.74	3.27

NSUCO				
Pursuits AB	Pursuits AC	Saccades HB	Saccades AB	Saccades AC
2.86	2.74	3.41	3.71	3.31
1.05	0.88	0.76	0.65	0.68
51	51	51	51	51
0.29	0.24	0.21	0.18	0.19
3.15	2.98	3.62	3.89	3.49
2.57	2.50	3.20	3.54	3.12