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Normative data on dynamic visual acuity for elders

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Normative data on dynamic visual acuity for elders

Abstract
PURPOSE: Previous studies have shown that dynamic visual performance remains relatively constant until mid-life then decreases gradually with increasing age. A new device that measures dynamic visual acuity using a stationary stimulus viewed during calibrated head movements shows excellent potential to monitor vestibular dysfunction. A normative database consisting of adults over 60 years of age was needed in order to expand on a previous study by Richards and Olmschenk.

METHODS: Twenty-eight volunteers over the age of 60 were evaluated using the inVision TM system by NeuroCom International, Inc. Each subject was tested using three protocols: clinical test of sensory interaction and balance (CTSIB) using the posturography platform, dynamic visual acuity (OVA) and gaze stabilization test (GST) using the head-borne accelerometer. For OVA and GST, subjects were instructed to move their heads back and forth (as if to say "no") at different velocities while making a forced choice as to the orientation of a tumbling E presented on a computer screen.

RESULTS: The data obtained were combined with the data from Richards and Olmschenk's study. There tends to be a decrease in overall performance with age, with statistically significant differences in all variables for the 70's and 80's decades.

DISCUSSION: The age-related decrease in OVA is consistent with previous studies. With the normative database of the in Vision TM system expanded to include a larger age range, it can better be utilized to monitor vestibular dysfunction.

Degree Type
Thesis

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NORMATIVE DATA ON DYNAMIC VISUAL ACUITY FOR ELDERS

By

KYLENE MILLER, BS
JEANNIE DEHNE, BS

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
For the degree of
Doctor of Optometry
May 2007

Advisor: Bradley Coffey, OD
Authors:

Kylene Miller

Jeannie Dehne

Advisor:

Bradley Coffey, OD
BIOGRAPHY

Kylene Miller received a Bachelor of Science degree in biology from Washington State University in Pullman, WA. She will receive a doctorate of optometry from Pacific University College of Optometry in May, 2007. Kylene is a member of the American Academy of Optometry, the American Optometric Association, the American Optometric Student Association, the Oregon Optometric Physicians Association, and the Optometric Physicians of Washington. After graduation, she plans to practice in the Northwest.

Jeannie Dehne received a Bachelor of Science degree in vision science after attending the University of Minnesota, Twin Cities, and Pacific University, Forest Grove, Oregon. She will receive a doctorate of optometry from Pacific University College of Optometry in May 2007. Jeannie is a member of the American Optometric Association including the cornea and contact lens section, sports vision section and low vision section, the American Optometric Student Association, and the College of Optometrists in Vision Development. She hopes to practice on the east coast.
PURPOSE: Previous studies have shown that dynamic visual performance remains relatively constant until mid-life then decreases gradually with increasing age. A new device that measures dynamic visual acuity using a stationary stimulus viewed during calibrated head movements shows excellent potential to monitor vestibular dysfunction. A normative database consisting of adults over 60 years of age was needed in order to expand on a previous study by Richards and Olmschenk.

METHODS: Twenty-eight volunteers over the age of 60 were evaluated using the inVision™ system by NeuroCom International, Inc. Each subject was tested using three protocols: clinical test of sensory interaction and balance (CTSIB) using the posturography platform, dynamic visual acuity (DVA) and gaze stabilization test (GST) using the head-borne accelerometer. For DVA and GST, subjects were instructed to move their heads back and forth (as if to say "no") at different velocities while making a forced choice as to the orientation of a tumbling E presented on a computer screen.

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ACKNOWLEDGEMENTS

We would like to thank NeuroCom International, Inc. for their generous travel funding, compensation for participants, and for providing equipment for this project.
INTRODUCTION

As the human body ages, many degenerative changes naturally take place. In addition to common changes like joint and muscle weakness, there are many changes that occur involving the visual system. Some of the major changes include increasing pupillary miosis, increasing lenticular absorption of entering light, decreasing light-dark adaptation, decreasing color discrimination, and decreasing accommodation\textsuperscript{1,2}. The pupil and lens changes decrease retinal illumination and seem to have a direct effect on visual field sensitivity and contrast sensitivity. In aging patients, contrast sensitivity loss in particular is very common and often quantified. It has been shown that increasing age significantly reduces performance on contrast sensitivity tests, especially at higher spatial frequencies\textsuperscript{3}. Contrast sensitivity loss has also been linked with other age-related ocular changes like macular drusen\textsuperscript{4}. It has also been proposed that optical changes have less effect on decreased sensitivity than do neural cell loss and degeneration in the visual pathway\textsuperscript{5}. Whatever the cause, declining contrast sensitivity in elders is so common that it would likely have a significant effect on any other measurement of visual sensitivity. It is important, therefore, to carefully consider age when measuring visual tasks like acuity.

One common result of the physical changes seen with age is the increased incidence of falls that occur in the elderly population. Among older adults, falls are the leading cause of injury deaths\textsuperscript{6} and the most common cause of nonfatal injuries and hospital admissions for trauma\textsuperscript{7}. Although many of these falls in this age group can be attributed to natural physical limitations, it has been
found that some may be due to vestibular problems\textsuperscript{8}. Just like most other systems, the vestibular system is affected by increasing age. However, it also may be affected by injury, disease, and even some medications. In the normal functioning person, the vestibulo-ocular reflex (VOR) functions during head movements to limit retinal image instability. When vestibular disease is present, patients sometimes complain of unsteady visual sensations and blurred vision during head movements, two symptoms of oscillopsia. While walking or driving a car, oscillopsia is likely the result of an inability of the VOR to adequately compensate for head motion\textsuperscript{9}.

An indication of vestibular function and vestibulo-ocular reflex performance can be inferred by measuring dynamic visual acuity\textsuperscript{10}. Dynamic visual acuity, or DVA, is the threshold of visual resolution obtained during relative motion of the observer, the target, or both\textsuperscript{11}. When retinal slip exceeds 2 degrees/second, degradation of visual acuity occurs\textsuperscript{12}. DVA can also provide information relative to the probable side of lesion in a patient with a suspected unilateral peripheral vestibular deficit\textsuperscript{13,14}.

The inVision\textsuperscript{®} device (http://www.onbalance.com/neurocom/products/inVision.aspx), developed by NeuroCom International in 2003, has recently been used around the world for measuring dynamic visual acuity and gaze stabilization. In order for the device to provide helpful measurements in monitoring vestibular function, Coffey, Richards, and Olmschenk performed a study to establish normative data\textsuperscript{15}. In 2004, 54 volunteers, aged 23-57, were tested using inVision\textsuperscript{®}. Each subject was screened for significant health problems and none reported any
symptoms of impaired vestibular function. The subject group could, therefore, be labeled as "normal" for these testing purposes. The experimenters proposed that with the measurements taken, they would see a significant decrease in DVA with increasing age. Their results did not show this pattern, but it was noted that the oldest subject was only 57 years. Previous studies have found that dynamic visual performance remains relatively constant until mid-life and then decreases gradually with increasing age\textsuperscript{2,12,16,17}.

This purpose of our study was to gather normative data for subjects aged 60 and older. The same protocol was used in order to make this a continuation of the previous work done with younger subjects in our lab.\textsuperscript{15} Before beginning, we needed to establish test-retest reliability for the inVision\textsuperscript{®} system and protocol previously used. We retested 18 of the original subjects, and found that the reliability was acceptable to continue with the elders\textsuperscript{18}.

These new data will be useful for the diagnosis and monitoring of elders with vestibular dysfunction, especially in regard to interventions for prevention of falls. DVA appears to be more closely related to real-world tasks than other traditional visual assessment procedures\textsuperscript{2}. A successful vestibular rehabilitation program designed for hypofunctional patients has been found to significantly reduce the risk of falling\textsuperscript{8}. The inVision\textsuperscript{®} device can be used as an integral tool for monitoring a patient's vestibular system during such rehabilitation programs.

METHODS

Volunteers were recruited for this study by advertisements in two local newspapers as well as informational fliers posted and recruitment talks given at
local retirement communities. A $20 incentive was offered to encourage participation. Twenty-eight adult volunteers participated in this study. Table 1 displays the breakdown of age and gender of the participants.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Ages 60-69</th>
<th>Ages 70-79</th>
<th>Ages 80-89</th>
<th>Over 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1. Age and gender of participants

Each volunteer underwent a preliminary telephone interview to discuss eligibility. Requirements included being at least 60 years of age, ability to stand comfortably without support, ability to move the head from side to side comfortably without pain, and seeing well enough to function independently with daily activities. If the subject met these criteria, s/he was scheduled for testing in the laboratory. Upon arrival, each subject read and signed the informed consent document (see Appendix 1) to participate in the study as approved by the Institutional Review Board at Pacific University. Each subject also filled out a health history form to screen for any major medical problems and list current medications. The researchers then interviewed the subject about any vestibular problems, ear problems, head injuries, highest education level completed, preferred hand, preferred foot and current optical prescription. If the subject was wearing their spectacles, the lenses were verified using lensometry. The subjects were also asked to describe their current living arrangement (independent, community, assisted living), if they still drive and if they consider themselves to have an active lifestyle.
The researchers then administered pre-tests which included 6m monocular static visual acuity using a Bailey-Lovie logMAR chart, cover test at distance and near, ocular sighting preference and 40 cm stereoacuity using the Titmus circles in a Randot nearpoint stereo test (available from Bernell Corporation at www.bernell.com). Ocular sighting preference was determined in the following manner. The subject placed the right hand on top of the left hand to form a triangle. The subject was asked to fixate on the researcher’s right eye while slowly raising the hands until they could see the researcher’s eye through the triangle. The subject was then asked to lower the hands, fixate on the researcher’s left eye and repeat the process. The subject was then asked to place the left hand on top of the right hand and repeat the procedure again. The researcher noted which eye was preferred and how strongly it was preferred out of the four trials.

NeuroCom’s invision® device (see Figure 1) consists of a desktop PC with flat LCD screen, a posturography platform, a headborne accelerometer and the software to run the program. The first test the subject performed was a modified Clinical Test of Sensory Interaction and Balance (CTSIB) on the posturography platform (See Figure 2). The CTSIB is based upon classical Romberg testing and measures baseline vestibular function and balance in four subtests. After the subject removes the shoes, s/he stands on a hard surface. The subject is asked to stand up straight, keep the arms at the sides and look straight forward. Three 10 second trials are done with eyes open and then three 10 second trials are done with eyes closed. The subject then stands on a soft foam rubber pad and
repeats the same sequence of trials. The purpose of the CTSIB is to measure the amount of postural sway during the four subtests. If the subject's CTSIB results were normal, s/he could move on to the next assessment.

For the next two assessments, the subject was seated 10 feet from the flat LCD screen in a stationary chair. The headborne accelerometer was placed on the subject's head and comfortably adjusted (see Figure 3). Static visual acuity
was taken with the inVision® system using a black tumbling E inside a white circle on the LCD screen. The subject had to make a forced choice decision as to the orientation of the tumbling E: up, down, left, or right. The inVision® software reduced the size of the tumbling E in a descending staircase pattern until threshold was reached with 3 out of 5 choices being incorrect.

After threshold static acuity was taken, the subject proceeded with one of two tests: Dynamic Visual Acuity (DVA) or Gaze Stabilization Test (GST). The order of tests was assigned in an alternating fashion between subjects. For both tests the subject was asked to move the head back and forth (as if saying “no”) in a large sweeping motion while keeping the eyes fixated on the screen. For measurement of DVA, the head velocity is maintained at a minimum of 80 deg/sec, and target size is gradually reduced. For measurement of GST, the target size is maintained at a level slightly larger than the static VA threshold, and the required head velocity is gradually increased.
For the DVA test, the subject was asked to reach a head velocity of at least 80 deg/sec. Before the actual test began, a practice screen was used to provide feedback to the subject about head velocity. Once the subject felt comfortable maintaining the 80 deg/sec head speed, the actual test began. If the subject’s head velocity ever fell below 80 deg/sec during the DVA test, the inVision® software would pause the test and present the practice screen again. Once the subject regained the correct head velocity, the test would continue.

During the DVA test, a black tumbling E was presented for 75 msec in the center of the white LCD screen. Immediately after the tumbling E was presented, the subject made a forced-choice decision as to the orientation of the E. The subject was encouraged to guess at each presentation if s/he was uncertain about the orientation. The inVision® software presented the tumbling E’s in a descending staircase fashion until the subject reached the threshold for DVA when 3 out of 5 trials were incorrect. The threshold acuity and terminal head velocity were measured for both rightward and leftward head movements separately in order to compare the results. The threshold acuity value was subtracted from the subject’s static visual acuity value to obtain the “DVA Loss.”

The GST assessment required the tumbling E stimulus size to be held constant while the subject gradually increased head rotation velocity. The tumbling E size was set at 0.2 logMAR larger than the subject’s static visual acuity. The subject was asked to start with a minimum head velocity of 80 deg/sec; the inVision® software increased the minimum head velocity by 10 deg/sec for each correct response given until threshold was reached with 3 out of
5 incorrect. The inVision® software recorded the subject's threshold velocity separately for rightward and leftward head movements.

After the subject had completed both the DVA and GST sections, s/he performed the modified CTSIB again in order to determine if the tests had any impact on their balance or vestibular function. The entire procedure took about 30 minutes per subject including the pre-testing.

The inVision® measurement variables included the following:

- SVA: static logMAR VA
- L DVA: threshold DVA for leftward head movement
- R DVA: threshold DVA for rightward head movement
- L DVA Vel: actual leftward head velocity when the L DVA threshold is measured
- R DVA Vel: actual rightward head velocity when the R DVA threshold is measured
- L GST: terminal leftward head velocity during GST measurement
- R GST: terminal rightward head velocity during GST measurement
- L DVA loss: loss in leftward DVA from static VA measurement
- R DVA loss: loss in rightward DVA from static VA measurement

RESULTS

The measurements taken from inVision® testing were analyzed using a one-way ANOVA for independent groups with decade of age as the independent variable. Acceptable probability was set at $p < 0.05$. If a variable was shown to be significant, a post-hoc analysis was done using the Fisher Pooled Least Mean Square Difference method. Refer to Appendix 2 for the complete data set. Due to the small sample size of the 90's decade ($n=1$), that group was not included in the statistical analysis. The comparisons shown here include data for younger subjects tested previously in our lab using the identical protocols\textsuperscript{15}. The age distribution for that study is shown in Table 2.
There tends to be a decrease in overall performance with age, with statistically significant differences in all variables for the 70's and 80's decades. An age-related difference in static visual acuity (SVA) was found \((p=0.0001)\); logMAR SVA decreased with increased age (see Figure 4). Both the 70's and 80's decades were significantly different from all other decades. Also, the 60's and 50's decades were significantly different from the 20's decade.

There was also an age-related difference in average terminal velocity during GST \((p=0.0004)\), showing that the maximum achievable terminal velocity decreased with increasing age (Figure 5). The 60's, 70's and 80's decades were all significantly different than the 20's, 30's and 50's decades. There were no significant differences found between leftward and rightward head motion on GST performance.

<table>
<thead>
<tr>
<th>Ages</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>21</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2. Age of participants from Coffey, Richards, Olmschenk 2004 study.
Threshold dynamic visual acuity (DVA) also showed an age-related difference (p=0.0001), with the 70's and 80's decades being significantly different from all other decades. No difference was found between the actual head velocity when the DVA threshold was measured for either leftward or rightward movement (see Figures 6 and 7).
Dynamic visual acuity loss from the static acuity (DVA loss) showed an age-related difference (p=0.0027), demonstrating greater dynamic visual acuity loss with increasing age (see Figure 8) that could not be accounted for by the age-related difference in SVA. The 80's decade was significantly different from the 20's, 30's, 40's, 50's and 60's decades, while the 70's decade was different from the 20's, 30's, 40's and 50's decades. Again, there was no difference in leftward vs. rightward DVA loss performance.
DISCUSSION

Past studies have used a variety of methods for measuring DVA. Some strategies have involved an acuity target that is in motion, while the subject remains stationary\(^2\). Others have used a stationary target and a walking subject\(^9,19\), or even whole body rotation\(^20,21\). Most often, however, there has been a stationary target with either passive or active rotation of the subject's head\(^12,14,15,22\). We believe that horizontal rotation of the subject's head while viewing a stationary target is the closest representation to real life motion during many daily activities. The target has also varied in historical methods of DVA measurement. Past targets include lines of Snellen letters, lines of numbers, a Landolt C, and a tumbling E. Dannenbaum showed that better consistency in DVA measurements could be achieved when using a tumbling E target\(^22\). With head movement and a stationary tumbling E, the *inVision\(^\circledR* protocol uses reliable methods for DVA measurement.

A recent study involving the *inVision\(^\circledR* device for measuring dynamic visual acuity showed no significant relationship between dynamic visual acuity and age\(^15\). However, the study was limited by maximum age of subjects being 57 years. The current study was designed to include subjects over the age of 60 while maintaining the same protocols as the original study. When the results of both studies were combined, it was found that there is, indeed, a significant effect of increasing age on dynamic visual acuity. This agrees with previous studies that have found similar effects of age on DVA\(^2,12,16,17\). The results also show an age-related difference in average terminal velocity during gaze stabilization,
showing that the maximum achievable terminal velocity decreased with increasing age.

For all age groups, no significant differences in dynamic visual acuity threshold or gaze stabilization terminal velocity were found between leftward and rightward head movements. This would be expected for "normal" subjects with normal vestibular function. Previous studies have found significant directional DVA loss in subjects with intracranial lesions present that affect vestibular function\(^\text{14}\). There is greater DVA loss with ipsilesional head movement when compared to contralesional movement. A significant directional difference in DVA loss could be used to distinguish a vestibulopathic subject from a normal subject, as well as determine on which side a suspected lesion is present. In this way, the inVision\(^\text{®}\) system may be implemented as a useful screener for vestibular problems. This would be especially beneficial for elders, who sustain a greater risk of injury with vestibulopathic-related falls.

When discussing DVA and age, it is relevant to revisit the issue of contrast sensitivity. We know that there is usually a decline in both DVA and CS with increasing age. It is difficult to know for sure how one influences the other. Long measured DVA in younger subjects with low-luminance conditions, as well as in older subjects with high-luminance conditions\(^2\). With overall retinal illumination measured to be approximately equivalent, there was no significant difference in measured DVA between age groups, suggesting that the smaller pupils of elders may be responsible for some portion of the reduced CS and DVA reported in other studies. Based upon our data, however, there seems to be a direct effect
of aging on DVA, since there were significant age-related decreases in DVA above and beyond the age-related effects on SVA (expressed as DVA loss).

Improvements of this study likely would have been made with a larger sample size of elders. Although each subject was asked about ocular disease during the screening process for participation, no objective ocular exam was conducted. It would have been helpful to have examined each subject for ocular conditions prior to DVA measurement. Our results may have been better understood had we more closely considered the affects of significant maculopathy, cataracts, or even pseudophakia.

Overall, we have been successful in measuring DVA in subjects with normal vestibular function aged 20 through decade 80. Now, with a more appropriate range of ages included, a more complete set of normative DVA values has been developed for the inVision® system. The normative database will benefit from expansion in the future, especially for elder subjects.
Appendix 1. Consent Form

Pacific University
Informed Consent to Act as a Research Participant
Dynamic Visual Acuity Normative Data

Investigator(s) Contact Information:
Dr. Bradley Coffey, Pacific University College of Optometry coffeyb@pacificu.edu
Jeannie Buchholz buch5820@pacificu.edu
Kylene Miller kymiller@pacificu.edu

1. Introduction & Background Information
You are invited to be in a research study of normative data for a new method of measuring dynamic visual acuity. Please read this form carefully and ask any questions you may have before agreeing to be in this study. This study is being conducted by Dr. Bradley Coffey. The purpose of this study is to obtain normative data for various age groups for a new method of measuring dynamic visual acuity.

2. Procedures
If you agree to be in this study, we will ask you to do the following things: You will wear a measurement device on your head and complete three tasks: computerized posturography, gaze stabilization, and dynamic visual acuity. The first task involves attempting to stand still on both a firm surface and a foam pad, both with eyes open and with eyes closed. For the gaze stabilization test, you will sit in a chair ten feet from a computer screen wearing lightweight headgear while swinging your head back and forth horizontally. When your head is moving fast enough, a Snellen tumbling "E" will appear on the screen and you will be asked to identify the correct orientation verbally. If you identify the orientation correctly, the rate of head movement is incrementally increased until you are unable to correctly identify the stimulus of constant size. The dynamic visual acuity test consists of the same setup as the gaze stabilization test. For this test, the rate of head movement remains constant while the size of the stimulus letter is incrementally decreased until you can no longer correctly identify it. You will spend about 30-40 minutes for the testing and will not need to return.

3. Risks & Benefits
None of the procedures conducted during the dynamic visual acuity study should pose any significant risks. During the balance stability test, there is a small risk for loss of balance. Investigators will be present to provide support at all times. A harness system will be readily available and used if the investigators deem it necessary or you prefer to use it. During head rotation, there is a small risk that you may experience symptoms of dizziness, nausea, and/or motion sickness. There is also a small risk of neck injury due to head rotation. You will be in full control of your head movement during the entire testing procedure and may report these symptoms at any time to the investigators and/or request to discontinue the testing. If you are experiencing these symptoms, you should not drive a motor vehicle until the symptoms subside. Possible benefits include further knowledge gained about dynamic visual acuity and particularly this method of measuring it. You may also receive documentation of your testing results upon request. The data from this study will be used as comparative data for NASA astronauts who have completed the same testing protocol.
4. Alternatives Advantageous to Participants
   Not applicable

5. Participant Payment
   You will receive compensation in the form of $20.00 cash for your participation.

6. Promise of Privacy
   The records of this study will be kept private. The individual data will be kept on the computer in the research lab which remains locked at all times. If the results of this study are to be presented or published, we will not include any information that will make it possible to identify a participant. Research records will be stored securely and only researchers will have access to the records.

7. Voluntary Nature of the Study
   Your decision whether or not to participate will not affect your current or future relations with Pacific University. If you decide to participate, you are free to not answer any question or withdraw at any time without prejudice or negative consequences.

8. Compensation and Medical Care
   During your participation in this project you are not a Pacific University clinic patient or client, nor will you be receiving complete care as a result of your participation in this study. If you are injured during your participation in this study and it is not the fault of Pacific University, the experimenters, or any organization associated with the experiment, you should not expect to receive compensation or medical care from Pacific University, the experimenters, or any organization associated with the study.

9. Contacts and Questions
   The experimenters will be happy to answer any questions you may have at any time during the course of the study. The experimenter can be reached at 503.352.2880 or by email at coffeyb@pacificu.edu. If you are not satisfied with the answers you receive, please call the Institutional Review Board Chair, Dr. Karl Citek, at (503) 352-2126 to discuss your questions or concerns further. Although Dr. Citek will ask your name, all complaints will be kept in confidence.

10. Statement of Consent
    I have read and understand the above. All my questions have been answered. I am 18 years of age or older. I have been given a copy of this form to keep for my records.

Participant's Signature ___________________________ Date ____________

Participant's printed name ____________________________

Investigator's Signature ___________________________ Date ___________
Appendix 2. Variables grouped by decade

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>20's</th>
<th>30's</th>
<th>40's</th>
<th>50's</th>
<th>60's</th>
<th>70's</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>mean</td>
<td>s.d.</td>
<td>n</td>
<td>mean</td>
<td>s.d.</td>
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<td>logMAR</td>
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<td>-0.19</td>
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<td>-0.12</td>
<td>0.10</td>
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<tr>
<td>L GST</td>
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<tr>
<td>L+R/2 GST vel</td>
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<td>93.08</td>
<td>23.76</td>
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<td>deg/sec</td>
<td>25</td>
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<td>105.40</td>
<td>8.80</td>
<td>6</td>
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<td>logMAR</td>
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<td>-0.20</td>
<td>0.11</td>
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<td>-0.29</td>
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REFERENCES

1  Carter TL. Age-related vision changes: a primary care guide. Geriatrics 1994; 49(9):37-44.