References

Bronkhorst, A. W., Veltman, J. A., & Breda, L. (1996). Application of a three-dimensional auditory display in a flight task. Human Factors, 38, 23-33.

Brown, B. (1972a). Dynamic visual acuity, eye movements and peripheral acuity for moving targets. Vision Research, 12, 305-321.

Brown, B. (1972b). The effect of target contrast variation on dynamic visual acuity and eye movements. Vision Research, 12, 1213-1224.

Brown, B. (1972c). Resolution thresholds for moving targets at the fovea and in the peripheral retina. Vision Research, 12, 293-305.

Burg, A. (1966). Visual acuity as measured by dynamic and static tests: A comparative evaluation. Journal of Applied Psychology, 50, 460-466.

Burg, A., & Hulbert, S. (1961). Dynamic visual acuity as related to age, sex, and static acuity. Journal of Applied Psychology, 40, 111-116.

Hoffman, L. G., Rouse, M., & Ryan, J. B. (1981). Dynamic visual acuity: A review. Journal of the American Optometric Association 52, 883-887.

Long, G. M., & Garvey, P. M. (1988). The effects of target wavelength on dynamic visual acuity under photopic and scotopic viewing. Human Factors, 30, 3-13.

Long, G. M., & Kearns, D. F. (1996). Visibility of text and icon highway signs under dynamic viewing conditions. Human Factors, 690-701.

Long, G. M., & Riggs, C. A. (1991). Training effects on dynamic visual acuity with free-head viewing. Perception, 20, 363-371.

Long, G. M., & Rourke, D. A. (1989). Training effects on the resolution of moving targets-dynamic visual acuity. Human Factors, 31, 443-451.

Ludvigh, E., & Miller, J. W. (1958). Study of visual activity during the ocular pursuit of moving test objects. I. Introduction. Journal of the Optical Society of America, 45, 799-802.

Miller, J. W. (1958). Study of visual activity during the ocular pursuit of moving test objects. II. Effects of direction of movement, relative movement, and illumination. Journal of the Optical Society of America, 48, 803-808.

Miller, J. W., & Ludvigh, E. (1962). The effect of relative motion on visual acuity. Survey of Opthamology, 7, 83-116.

Morrison, T. R. (1980). A review of dynamic visual acuity. NAMRL Monograph - 28. Pensacola, FL: Naval Aerospace Medical Research Laboratory.

National Research Council (NRC) Committee on Vision (1985). Emergent Techniques for Assessment of Visual Performance. Washington DC: National Academy Press.

National Research Council Committee on Vision, Working Group 55 (1982). Aging and visual function of military pilots: a review. Aviation, Space, and Environmental Medicine, 53, 747-757.

Neisser, U. (1967). Cognitive Psychology. New York: Appleton-Century Crofts.

Perrot, D. R., Cisneros, J., McKinley, R. L., & D'Angelo, W. R. (1996). Aurally aided visual search under virtual and free field listening conditions. Human Factors, 38, 702-716.

Prestrude, A. M. (1987). Dynamic visual acuity in the selection of the aviator. In R. Jensen (Ed), Proceedings of the Fourth International Symposium on Aviation Psychology. Columbus, OH: Ohio State University Press.

Schiffman, H.R. (1990). Sensation and Perception (3rd ed). New York: John Wiley and Sons.

Prestrude, A. M. (1987). Dynamic visual acuity in the selection of the aviator. In R. Jensen (Ed), Proceedings of the Fourth International Symposium on Aviation Psychology. Columbus, OH: Ohio State University Press.

Shevlin, J. P. (1996). The effects of random linear target direction in a computerized dynamic visual acuity task. Unpublished master's thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Shevlin, J. P., Prestrude, A. M., & Shevlin, K. A. (1997). The effects of random linear target direction in a computerized dynamic visual acuity task. In R. Jensen (Ed), Proceedings of the Ninth International Symposium on Aviation Psychology. Columbus, OH: Ohio State University Press.

Shevlin, K. A., Shevlin, J. P., & Prestrude, A. M. (1996) Dynaque [Computer Software]. Orlando FL: Authors.

Shevlin, K. A, Shevlin, J. P., & Prestrude A. M. (1998) Dynaque 4 [Computer Software]. Alexandria VA: Authors.

Appendix A: Derivation of Measures of Velocity and Size

Discussion

The size (visual angle) of a target as imaged on the retina is a function of the target's physical size and the target's distance from the observer. This relationship is expressed by one of two formulae:

$$\tan b / 2 = s / 2d$$

or

$$\tan b = s / d \quad \text{(for angles less than 10 deg)}$$

Where: b = visual angle in degrees s = physical size of target; d = viewing distance.

(Schiffman, 1990)

Because the visual angle changes as viewing distance changes, two issues had to be resolved to display and move targets on a flat screen: target size and target velocity.

Target Size

Most DVA research used hemicylindrical screens to display moving visual targets. These round screens enabled researchers to hold viewing distance constant. Consequently, the retinal image size (visual angle) of a moving target remained constant when projected onto the hemicylindrical screen.

Because the computer screen is flat, the viewing distance to targets displayed in the peripheral areas of the screen will be greater than the viewing distance to targets displayed in the center of the screen. Because of this discrepancy in viewing distance, targets displayed on the screen periphery will register a smaller visual angle on the retina. As a target moves towards the center of the screen, the visual angle projected onto the retina will increase in size. When the target moves away from the center of the screen the retinal image of the target will decrease in size. In the current study, viewing distance to the center of the screen is 34 cm and viewing distance to the periphery of the screen is 37 cm. Based on these viewing distances and the formula described above, targets displayed on the periphery of the screen will be perceived as at most 8% smaller than targets displayed in the center of the screen. For example, the perceived

size of the smallest target (.26 mm gap size), would appear to be 2.4 min displayed peripherally and 2.6 min displayed centrally. Similarly, the next largest target size (.52 mm) would appear 4.9 min displayed peripherally and 5.3 min displayed centrally.

All measurements of target size used in this study represented the largest possible visual angle imaged by a target on the retina. The d in the formula tan B = s/d is no greater than the 34 cm viewing distance, which is the minimum distance available to observers. Table A1 compares the target sizes proposed in the current study with the target sizes used in prior research (Long & Riggs, 1991; Long & Roarke, 1989)

Target Velocity

Target velocities in DVA research have been conventionally expressed in deg/s, based on the angle of arc over which the targets traversed on the hemicylindrical screens. The measurement of deg/s in the current study reflects a similar concept, although has slightly different perceptual implications from conventional DVA measures of deg/s. This study based flat screen velocity measures of deg/s on prior research using the angular measure of deg/s. Table A2 outlines the formulae used to calculate velocity in deg/s for the current study and illustrates the flat screen distance the targets will traverse based on a minimum viewing distance of 34 cm.

As opposed to traveling along the physical length of the arc of "x" degrees per second, as has been the convention, the current targets travelled along the physical length of the base of this same arc per second. Because the shortest distance between two points is a line, the length of the base of an arc is always shorter than the length of the arc itself. Consequently, in the current study, flat screen targets traversed a shorter physical distance in the same amount of time compared to conventional hemicylindrical screen measures. Perceptually, this distinction was manifested in predictable distortion of apparent target size, discussed above.

Table A1

Target Critical Detail (Gap) Visual Angle (B) in Minutes in Current and Prior Studies

Gap Size (mm) Current Study	B (minutes) Current Study	B (minutes) Prior Studies*
.26	2.6	2.3
.52	5.3	3.4
.87	7.9	4.6
1.04	10.6	5.7
1.30	13.1	6.8
1.56	15.8	9.8
1.82	18.4	11.4
2.08	21.0	13.7
2.34	23.7	17.4
2.60	n/a	19.0
2.86	n/a	26.7
3.38	n/a	31.8
3.64	n/a	43.2

Notes. Computations for current study used the formula b = {inv tan (s/d)} 60, which is an algebraic derivation of the formula presented by Schiffman (1990). In this formula, b = visual angle in minutes, s = physical size of the target, d = viewing distance, 60 = a correction factor applied to translate degrees into minutes. The visual angles of targets presented in the "prior studies" column reflects the sizes used by Long and Riggs (1991) and Long and Roarke (1989). Although the range of target sizes in the current study is similar to the ranges used in prior studies, the increments between target sizes in the current study are equal; whereas, the sizes used in earlier studies were more sensitive at the smaller target end of the scale. These sizes are computed based on a viewing distance of 34 cm using a 17" monitor.

Table A2

Computer Display Properties and Measures of Velocity based on Exposure Times (ET)

Display Movement Properties			Path Length (mm) Based on ET (ms)				Velocity
# Pixels Moved	Frequency	Rate (mm/ms)	1000 ms	570 ms	370 ms	170 ms	(deg/s)
1	2 ms	.13	130	74.1	48.1	22.1	22.04
1	1 ms	.26	260	148.2	96.2	44.2	44.95
3	2 ms	.39	390	222.3	144.3	66.3	66.99
2	1 ms	.52	520	296.4	192.4	88.4	99.76

Notes. Monitor is 17 inch 0.26 mm dot pitch. Based on minimum viewing distance of 34cm. Formula for Velocity V = arc sin [R/D], where V = velocity (deg/s), R = Rate (mm/s), and D = Viewing Distance (mm).

Appendix B: Detailed Directions to Participants

(Actual Computer text displayed in **BOLD** type)

When initiating the program, the computer provided the following technical information to verify display settings:

Mode is (graphics mode type)
Max screen size in pixels = [x max] x [y max]
Press return to continue

SCREEN CLEARS
DISPLAY CHANGES TO LEFT HALF WHITE, RIGHT HALF BLACK AND WAITS FOR A KEY TO BE PRESSED

The split half screen display was used to calibrate the luminance of the target and the background at the beginning of each session.

SCREEN CLEARS

The computer then prompted the experimenter for the following information from the data base:

Please enter subject number:
Please enter the last name of subject:
Please enter the first name:
Please enter SSN (nnn-nn-nnnn):
Please enter the age of subject:
Please enter the gender [M/F]:
Please enter the session number:

The computer then presented the experimenter with a series of toggle options to choose static vs. dynamic, fixed vs. random, text cues vs. no text cues, familiarization vs testing. Depending on the settings, the computer would run the appropriate program.

Observers then viewed the following general directions:

************ INTRODUCTION ************

The target for all visual testing on this computer program is the letter 'C'. The gap in the letter 'C' will be pointed in one of four directions: towards the top, bottom, right, or

left of the computer screen.

Your task is to determine the direction in which the gap is pointing, and input your decision via the keyboard using the arrow keys. The computer will first present the largest 'C', and continue to present smaller 'C's until it determines the smallest 'C' you can correctly identify.

Press the Return (or Enter) key to continue

NEXT SCREEN

The computer will beep approximately one second before each target appears. The computer will wait to present the next target until you input your answer for the current target. Therefore, you must guess. Accuracy is more important than speed. Do the best you can.

Press the Return (or Enter) key to continue

The experimenter then adjusted the height of the chair to raise each participant to the common viewing height, which corresponded to the center of the computer monitor.

Prior to further familiarization and testing, the experimenter supplemented the computer instructions, emphasizing four points:

1) The purpose of the horizontal bar is to prevent you from getting too close to the screen and "cheating"; however, it is to your advantage to be as close to screen as the bar will allow.

2) The input mechanism is the arrow keys, and most people find it easiest to use their index finger to input left, their ring finger to input right, and their middle finger to discriminate between up and down.

3) The experimenter will remain in the room in case the computer malfunctions or you have questions.

4) Each session will begin with some practice rounds to ensure that you feel comfortable with the task and the input mechanism. Once you feel comfortable with

the task and have entered at least three decisions, let me know and I will switch the computer to the test role.

************ Static Threshold Practice ************

For this test, the 'C' will appear briefly in the middle of the screen and will not move. This practice round will familiarize you with the task.

The horizontal bar near your forehead will ensure you view the screen from no closer than 29 cm. It is to your advantage to be as close to the screen as the bar will allow. You may rest your forehead against the bar.

If you have any questions, please contact the experimenter now.

Press the Return (or Enter) key to continue with the practice round.

FOR EACH ROUND BEGINNING…
You have {number of rounds} **rounds remaining**

SCREEN CLEARS PRESENTS TARGETS

IF OBSERVER ENTERS IN THE CORRECT RESPONSE:
Correct!
Press the return (or enter key) to continue.

IF OBSERVER ENTERS INCORRECT RESPONSE:
Incorrect.
Press the return (or enter key) to continue.

THE COMPUTER PROVIDED FEEDBACK (CORRECT OR INCORRECT AFTER EACH RESPONSE). ONCE THE OBSERVER INDICATED COMFORT WITH THE TASK THE EXPERIMENTER SWITCHED THE COMPUTER TO THE STATIC TEST MODE, EMPHASIZING TWO POINTS:

1) Unlike the familiarization round, the testing will be conducted in three rounds and the computer will provide no feedback after each guess. Instead, the computer will continue to present Cs until it establishes the smallest c you can correctly identify.

2) Feel free to take a break between rounds (when there is text on the screen). Do not take a break during a round (when the computer is presenting Cs), or you may miss one.

THE COMPUTER STARTED THE STATIC TEST ROUND

************ Static Threshold Test ************

For this test, the 'C' will appear briefly in the middle of the screen and will not move. This test is conducted in three rounds.
NOTICE: The testing round will not give any indication as to correct or incorrect, but will proceed to the next 'C'.

The horizontal bar near your forehead will ensure you view the screen from no closer than 29 cm. It is to your advantage to be as close to the screen as the bar will allow. You may rest your forehead against the bar.

If you have any questions, please contact the experimenter now.

Press the Return (or Enter) key to continue with the threshold testing round.

SCREEN CLEARS
FOR EACH ROUND BEGINNING…
You have {number of rounds} **rounds remaining**
Press the return (or enter key) to continue.

SCREEN CLEARS AND PRESENTS TARGETS. REPEATS THIS PROCESS UNTIL ALL THREE STATIC THRESHOLDS ARE RECORDED (0 DEG/S X 170, 370, 570 MS).

Once the participant completed the static testing, the experimenter switched the computer to the dynamic familiarization round. Participants in the known and unknown origintarget presentation conditions received instructions relevant to their respective tasks. The experimenter supplemented the computer instructions, emphasizing the following points:

1) This is a slightly different task. Again, you will be provided with some practice trials to familiarize yourself with the task, and I will switch the computer to the test mode.

2) You must complete a minimum of three decisions.

The computer then initiated the dynamic familiarization as follows:

DYNAMIC PRACTICE
************ Moving Threshold Practice ************

This test is similar to the static test, except the 'C' will be moving across the screen in any one of six directions - horizontally:
left to right
right to left
diagonally:
top-left to bottom-right
top-right to bottom-left
bottom-left to top-right
bottom-right to top-left

Your task is the same as in the preceding test. Input the direction of the gap in the 'C' via the keyboard. This practice session will familiarize you with the task.

Press the Return (or Enter) key to continue

IF THE OBSERVER WAS IN THE UNKNOWN ORIGIN CONDITION
The words, Next target, will appear in the center of the screen before each target is presented.

IF THE OBSERVER WAS IN THE UNKNOWN ORIGIN CONDITION
The words
"Top Right"
"Right"
"Bottom Right"
"Top Left"
"Left" or
"Bottom Left"

will appear in the center of the screen before each target is presented. These words indicate the screen location from which the next target will appear.

THE INSTRUCTIONS FOR ALL PARTICPANTS THEN CONTINUED IN THE FOLLOWING MANNER:

The horizontal bar near your forehead will ensure you view the screen from no closer than 29 cm. It is to your advantage to be as close to the screen as the bar will allow. You may rest your forehead against the bar.

Again, you must guess, and accuracy is more important than speed. Do the best you can.

Press the Return (or Enter) key to continue with the practice round.
FOR EACH ROUND BEGINNING…
You have {number of rounds} **rounds remaining**

SCREEN CLEARS PRESENTS TARGETS

IF OBSERVER ENTERS IN THE CORRECT RESPONSE:
Correct!
Press the return (or enter key) to continue.

IF OBSERVER ENTERS INCORRECT RESPONSE:
Incorrect.
Press the return (or enter key) to continue.

THE COMPUTER PROVIDED FEEDBACK (CORRECT OR INCORRECT, AFTER EACH RESPONSE). ONCE THE OBSERVER INDICATED COMFORT WITH THE TASK THE EXPERIMENTER SWITCHED THE COMPUTER TO THE STATIC TEST MODE, EMPHASIZING TWO POINTS:

1) Unlike the familiarization round, the testing will be conducted in twelve rounds and the computer will provide no feedback after each guess. Instead, the computer will continue to present Cs until it establishesthe smallest c you can correctly identify for that round.

2) Feel free to take a break in between rounds (when there is text indicates "you have---- rounds remaining) Do not take a break during a round (when the computer is presenting Cs), or you may miss one.

******* DYNAMIC TEST*********************

This test is similar to the static test, except the 'C' will be moving across the screen in any one of six directions - horizontally:

left to right
right to left
diagonally:
top-left to bottom-right
top-right to bottom-left
bottom-left to top-right
bottom-right to top-left

Your task is the same as in the preceding test. Input the direction of the gap in the 'C' via the keyboard. This test will be conducted in twelve rounds, each using a different combination of target speed and display time.

NOTICE: The testing round will not give any indication as to correct or incorrect, but will proceed to the next 'C'.

IF THE OBSERVER WAS IN THE UNKNOWN origin CONDITION
The words, Next target, will appear in the center of the screen before each target is presented.

IF THE OBSERVER WAS IN THE UNKNOWN origin CONDITION
The words
"Top Right"
"Right"
"Bottom Right"
"Top Left"
"Left" or
"Bottom Left"
will appear in the center of the screen before each target is presented. These words indicate the screen location from which the next target will appear.

THE INSTRUCTIONS FOR ALL PARTICPANTS THEN CONTINUED IN THE FOLLOWING MANNER:

Press the Return (or Enter) key to continue

The horizontal bar near your forehead will ensure you view the screen from no closer than 29 cm. It is to your advantage to be as close to the screen as the bar will allow. You may rest your forehead against the bar.

Again, you must guess, and accuracy is more important than speed. Do the best you can.

Press the Return (or Enter) key to continue with the moving test round.

SCREEN CLEARS
FOR EACH ROUND BEGINNING…
You have {number of rounds} **rounds remaining**
Press the return (or enter key) to continue.

SCREEN CLEARS AND PRESENTS TARGETS. REPEATS THIS PROCESS UNTIL ALL TWELVE DYNAMIC THRESHOLDS ARE RECORDED (22, 45, 70, 100 DEG/S) X (170, 370, 570 MS).

Appendix C. USMA Independent Review Board Approval

DEPARTMENT OF THE ARMY
UNITED STATES MILITARY ACADEMY
West Point, New York 10996

REPLY TO
ATTENTION OF

MADN-BSL 6 OCT 1998

MEMORANDUM THRU

DR SEHCHANG HAH, RESEARCH COORDINATOR, DEPARTMENT OF BEHAVIORAL SCIENCES AND LEADERSHIP

COL JOHNSTON BEACH, PROFESSOR AND DIRECTOR, PSYCHOLOGY PROGRAMS, DEPARTMENT OF BEHAVIORAL SCIENCES AND LEADERSHIP

COL CHARLES F. BROWER IV, PROFESSOR AND HEAD, DEPARTMENT OF BEHAVIORAL SCIENCES AND LEADERSHIP

FOR COL KERRY PIERCE, DIRECTOR, OFFICE OF POLICY, PLANNING, AND ANALYSIS

SUBJECT: Application for Use of Human Participants in Research

1. **Title of the research:** Text Cues and Dynamic Visual Acuity (DVA)

2. **Principal researcher(s)/Supervisor(s)** MAJ Joseph P. Shevlin x 5637. Cadet researchers: NA

3. **Objectives of research:** This study is partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Psychology at Virginia Polytechnic Institute and State University. DVA refers to an observer's ability to resolve a critical detail in a target when there is relative motion between the observer and target. The study will investigate DVA using a computerized testing platform under several different viewing conditions (described below). This study will demonstrate that DVA is facilitated when the observer is aware of a target's origin. This study has implications for system design in any application where the operator is compelled to identify and act upon dynamic targets.

4. **Methods and procedure to be used:** Fifty USMA fourth class cadets will each be given the opportunity to participate in a single 45 minute session. The equipment and procedures are established and present no known hazards or risks to participants. Similar procedures and equipment have been approved and used over the last three years at USMA and at Virginia Tech. Once briefed on the purpose and procedures of the study, each participant will sign an informed consent form. Participants may be screened for Static Visual Acuity (SVA) to ensure they meet the minimum (20/40, near, corrected). With permission from the cadets and the optometry clinic, cadet optometry records may be accessed to determine near SVA. Following testing, participants will be thanked and debriefed. Participants will be treated IAW all APA ethical guidelines.

a. Task: Observers will be seated no closer than 29cm from a 17 inch computer monitor. A Landolt ring (similar to the letter "C") will be displayed and moved across screen. The observer's task is to determine which direction the gap in the "C" is facing, and input his/her response into the computer via the directional arrow keys. The "C" will continue to get smaller with each correct response, until the computer determines the smallest "C" the observer can correctly identify. The dependent variable is the size threshold (min) of the "C".

b. Between Subjects Variable: (Target Presentation). All moving targets will originate from one of six screen locations and move linearly to a point 180 degrees opposite their origin. Participants will be randomly assigned to one of the two presentation conditions. *Known Origin* targets will be preceded by text indicating their origination point ("top right", "right", "bottom right", "top left", "left", "bottom left" whereas *Unknown Origin* targets will be preceded by text indicating only "next target".

c. Within Subjects Variables. Within their assigned presentation condition, each observer will complete twelve threshold trials representing the factorial combination of three target Durations (170, 370, and 570 ms) x four target Velocities (22, 45, 70, and 100 deg/s). Following testing, participants will be thanked and debriefed. Participants will be treated IAW all APA ethical guidelines.

5. POC is MAJ Shevlin, x 5637.

JOSEPH P. SHEVLIN

Vita

Joseph P. Shevlin

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Business Address: Department of Behavioral Sciences and Leadership
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EDUCATION:

Civilian:

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Major: Psychology (Cum Laude)

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EMPLOYMENT:

1988-1990: Rifle Platoon Leader, Anti-Armor Platoon Leader, 82nd Airborne Division, Ft. Bragg NC

1990-1991: Company Executive Officer, 82nd Airborne Division, Ft Bragg NC, Saudi Arabia, and Iraq.

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HONORS AND AWARDS:

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Willard F. Rockwell and Presley L. Stevenson Scholarship Leadership Awards, Kappa Sigma.

Military:
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Meritorious Service Medal
Army Commendation Medal (x 2)
Army Achievement Medal (x3)
National Defense Service Medal
Army Service Ribbon
Southwest Asia Service Ribbon (x2)
Liberation of Kuwait Medal
Combat Infantryman's Badge
Expert Infantryman's Badge
Master Parachutist Badge
Pathfinder Badge
Ranger Tab