EFFECTS OF VISUAL PERCEPTUAL ASYMMETRIES ON PERFORMANCE WHILE USING AN AIRCRAFT ATTITUDE SYMBOLOGY

George A. Reis
Eric E. Geiselman
711 Human Performance Wing, Battlespace Visualization Branch,
Wright-Patterson Air Force Base, United States
Michael E. Miller
Air Force Institute of Technology, Systems Engineering and Management,
Wright-Patterson Air Force Base, United States

In applying the Arc-Segmented Attitude Reference (ASAR) symbology in head-mounted displays (HMDs), it is uncertain if there is an optimal position for the symbology within the display. Vision science literature regarding visual asymmetries suggests that performance may differ depending upon the combination of the location of this symbology within the visual field and whether the user is interpreting the symbology to make *categorical* judgments (e.g., is the aircraft rolling left or right?) or *coordinate* judgments (e.g., what is the aircraft's roll angle). Participants were asked to report aircraft roll and climb/dive angles of briefly presented ASAR symbology within the peripheral visual field on a monitor. There were no performance differences between the left and right ASAR positions in either the coordinate or categorical tasks. There were however trends consistent with horizontal-vertical anisotropy.

Augmented reality (AR) is used to enhance user situation awareness by presenting information in the form of symbols, text, pictures, or video over a real world scene to enhance information transfer. The enhancements can be located in the periphery of the user's visual field to avoid obscuring information with the user's central visual field, particularly when the user views the information within a helmet-mounted display (HMD). In these displays, the observer can either attend to the AR information overtly by making eye fixations on this information or covertly by processing the information without making a fixation. It is proposed that research in perceptual visual asymmetries may advise information design within HMD systems. This premise is derived from experimental research involving a central fixation and an assessment of peripheral visual performance (Hellige, 1993; Bradshaw, 1990; Bourne, 2006). Therefore, it is argued these experimental methods are representative of an observer's performance when covertly attending to peripherally-presented AR information while fixating on real world objects.

Karim & Kojima (2010) categorize perceptual asymmetries in the visual domain as within-field and between-field. In within-field asymmetries, perceptions of stimuli located at a certain location in the field of view (FOV) may differ based on the stimuli's characteristics (e.g., orientation and spatial frequency). In between-field asymmetries, perception of the stimuli differ due to their placement in the user's field of view. Differences in performance have been noted between the lower and upper, as well as between the left and right peripheral regions (Thomas & Elias, 2011; Brederoo, Nieuwenstein, Cornelissen, & Lorist, 2019). Pertinent to the current study, it has been suggested that the left visual field is better than the right in *coordinate* spatial processing and the right is better than the left at *categorical* spatial processing (Kosslyn 1989;

Jager & Postma, 2003). In categorical processing, we determine abstract, prepositional relations between objects (e.g., the cup is to the left of the plate). In coordinate processing, we invoke a measurement process (e.g., the cup is 10 cm away from the plate). The categorical/coordinate asymmetry research typically utilizes simple visual stimuli, thus it is unclear whether similar effects will be observed for more complex, applied visual stimuli. This study explores the effect of interpreting a version of the Arc-Segmented Attitude Reference (ASAR) symbology (Fisher & Fuchs 1992; Geiselman, Havig, & Brewer, 2000; Jenkins, 2008) in categorical and coordinate tasks in various regions of the peripheral FOV. This effort seeks to understand whether performance in categorical or coordinate tasks performed with the ASAR differs with FOV placement.

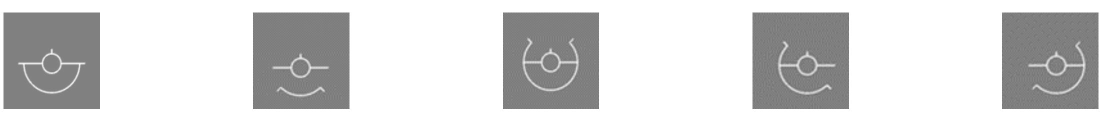
Method

Participants

Five males participated (mean age: 39 years, range: 22 – 52 years). One participant had experience as a pilot. All reported normal or corrected-to-normal vision.

Apparatus and Stimuli

The ASAR includes a fixed 'ownship' symbol that represents climb/dive angle by its relation to a half-circle arc surrounding the symbol as shown in Figure 1(A). During straight-and-level flight, the upper portion of the circle is not visible and represents the area above the horizon. The visible arc represents the area below the horizon. As the climb angle increases, the visible angle area of the arc narrows in proportion to the climb angle. Conversely, as the dive angle increases, the arc closes towards a circle. During rolling maneuvers, the arc rotates about the ownship symbol. The orientation of the ASAR is 'forward-reference,' depicting climb/dive and roll as if ownship is viewed from behind and the horizon is viewed as if looking forward.



A B C D E

Figure 1. The ASAR representing (A) straight and level flight. (B) 45° climb (C) 45° dive (D) 45° roll left (E) 45° roll right. At a climb/dive of 0°, the half-circle subtended 3.5° of visual angle. The ASAR symbology was presented as white against a gray background.

For application within the visible area of an HMD when the pilot is looking off-axis (away from the aircraft centerline), the ASAR can be small, permitting placement in various locations within the HMD. Thus, this symbology can be placed to reduce clutter and improve operational usability. For example, the ASAR may be placed near the top of the display in air-to-ground mode to move it away from weapon guidance symbology, which is typically presented in the lower portion of the display. For air-to-air, the symbology can be placed at the bottom of the display to de-clutter the upper portion of the display. Placement from one side of the display to the other may be based on separating the ASAR symbology from other forward stabilized symbology. Independent of the ASAR location, its interpretation as an attitude reference is consistent.

It can be argued that roll and climb/dive deviations from straight and level flight can be processed either as categorical or coordinate information, and this dichotomy has practical implications. In interpreting the ASAR, deciding if the symbology indicates a climb or dive, or a roll to the left or right, is a categorization process. This process is important when the pilot's intent is to maintain altitude and heading. On the other hand, determining the magnitude of a climb/dive or roll angle requires coordinate processing. This assessment is important when the pilot decides to change altitude at a specific angle or to maintain a specific roll angle for a certain resultant turn rate.

During the experiment, the participants observed the ASAR on a 23.6-inch ViewPixx display, with its center positioned 57 cm from the participants' eyes. The participants' heads were stabilized with a chin rest. Responses were registered on a SteelSeries XL Bluetooth gamepad controller.

Design and Procedure

Before testing began, participants spent 10 minutes controlling a low fidelity flight simulation during which they received instructions to become acquainted with the dynamic behavior of the ASAR. For each trial, participants fixated on a crosshair centered on the display. They initiated a trial by pressing a button on the right side of the controller. The ASAR was presented briefly for 80 msec. Trials were randomized, without replacement, in each block. A block included a combination of 9 attitude deviations (5° to 85°, at 10° increments) x 2 directions (rolling left and right for roll trials or climbing up and diving down for climb/dive trials) x 8 positions (15° of visual angle from the center of the display, 0° = E, 45° = NE, 90° = N, 135° = NW, 180° = W, 215° = SW, 270° = S, 315° = SE). Participants performed 10 blocks at each of the four combinations of attitude parameter (roll, climb/dive) and spatial processing task (categorical, coordinate), equaling a total of 5,760 trials. After presentation, the ASAR was replaced with a mask of static Gaussian noise to reduce visual persistence.

If the trial was characterized as a roll, categorical condition, participants were instructed to respond with their left thumb on the left or right button of the controller direction pad to match the actual roll direction indicated by the ASAR. Likewise, if the trial was a climb/dive categorical type, the participants responded by pressing the top button (meaning the aircraft was diving) or bottom button (meaning the aircraft was climbing), which map to the mechanization of an aircraft control stick. In both roll and climb/dive categorical trials, response time (RT) and accuracy were recorded. After a response, the Gaussian noise disappeared and the crosshairs appeared again to begin the next trial. In both roll and climb/dive trials, participants were instructed to prioritize accuracy.

If the trial was characterized as a roll, coordinate trial, after the ASAR disappeared in the periphery, the ASAR re-appeared in a straight and level attitude in the middle of the screen (visible against the noise background). The participants then attempted to replicate the roll or climb/dive position by pressing the direction buttons. After the participants obtained the attitude they believed to observe, they pressed a confirmation key and the crosshairs appeared. The Absolute Offset Error (AOE) between the actual ASAR attitude and the participants' response was recorded.

Participants performed either all roll or all climb/dive blocks first. The 10 roll and 10 climb/dive blocks were each divided into two groups (5 blocks categorical, 5 blocks coordinate) and these groups were alternately performed. The sequence of roll and climb/dive blocks and the categorical and coordinate groups were counterbalanced among four participants. The fifth participant received roll blocks first. Before the first time a roll or climb/dive block in combination with a categorical or coordinate tasking was performed, a training block of that combination was completed. Lastly, in every test block, five randomly chosen trials from that set were performed at the beginning to familiarize the participant of the condition being performed.

Results

Results of only the position effects on performance are presented. This statement is not intended to imply that there are no possible interactions between position and angular deviation and direction in roll or climb/dive. Before the data were assessed, values in RT and AOE that were outside of 3.5 standard deviations were identified as outliers and trimmed from the dataset. Accuracy in categorical trials was greater than 95% and there were no apparent tradeoffs between accuracy and RT. The means of RTs and AOEs from the trials in each participant x position cells were chosen to be analyzed. Figures 2 and 3 present AOEs and RTs for climb/dive and roll parameters, respectfully, as a function of position in the FOV.

Table 1 shows the results of the Friedman test carried out to ascertain differences in performance when the ASAR was presented in the eight different positions. Statistically significant differences in performance were observed in the combinations of Climb/Dive-Coordinate, Climb/Dive-Categorical and in Roll-Coordinate blocks. For each of these three combinations, Dunn-Bonferroni tests were performed. The results are shown in the lower portion of Table 1.

Discussion

In general, across all angular deviations and directions in climb/dive and roll, the data suggest no performance differences between the 180° and 0° positions (left vs right) in either the coordinate or categorical taskings. However, there appear to be visual processing differences of the ASAR across the FOV. In particular, the 180° position showed decreased RT and offset error when compared to some other positions. It may be the case that this effect results from pseudoneglect (Jewell & McCourt, 2000) or some other underlying visual attentional asymmetry. Other research (e.g., Corbett & Carrasco, 2011) discusses Horizontal-Vertical Anisotropy (HVA)—where performance on the east-west meridian of the visual field outperforms that of the north-south meridian. The results obtained here trend in line with a HVA as the 0° and 180° positions showed some performance advantages over the 90° and 270° positions. The results from this study indicate that visual asymmetries may exist that influence the design and configuration of HMD symbology.

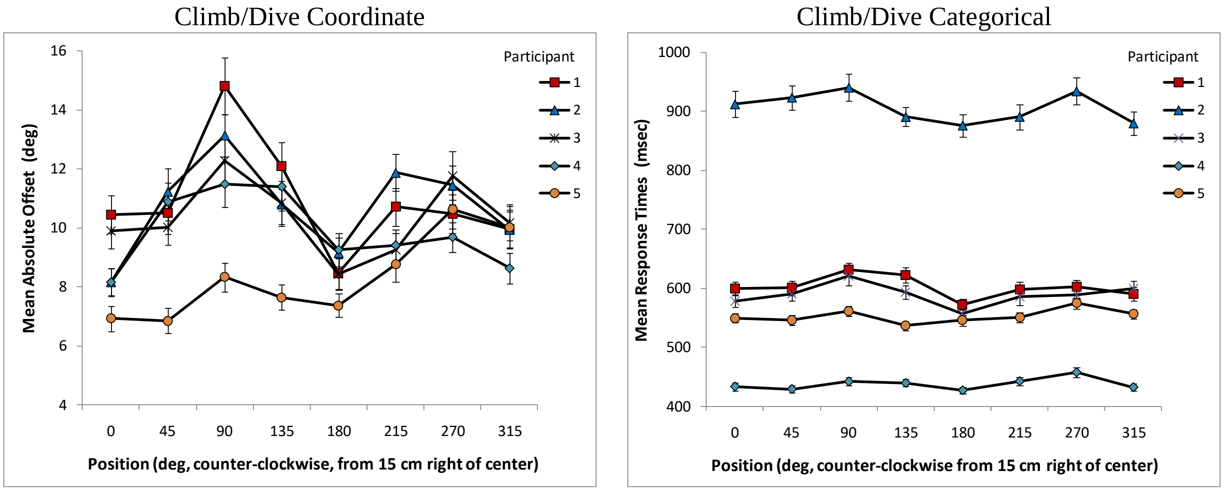


Figure 2. (Left) The mean absolute offsets and (Right) the mean response times across climb/dive directions and angular deviations, at coordinate and categorical trials, respectively, are plotted as a function of the position in the FOV. Errors bars represent ± 1standard error of the mean.

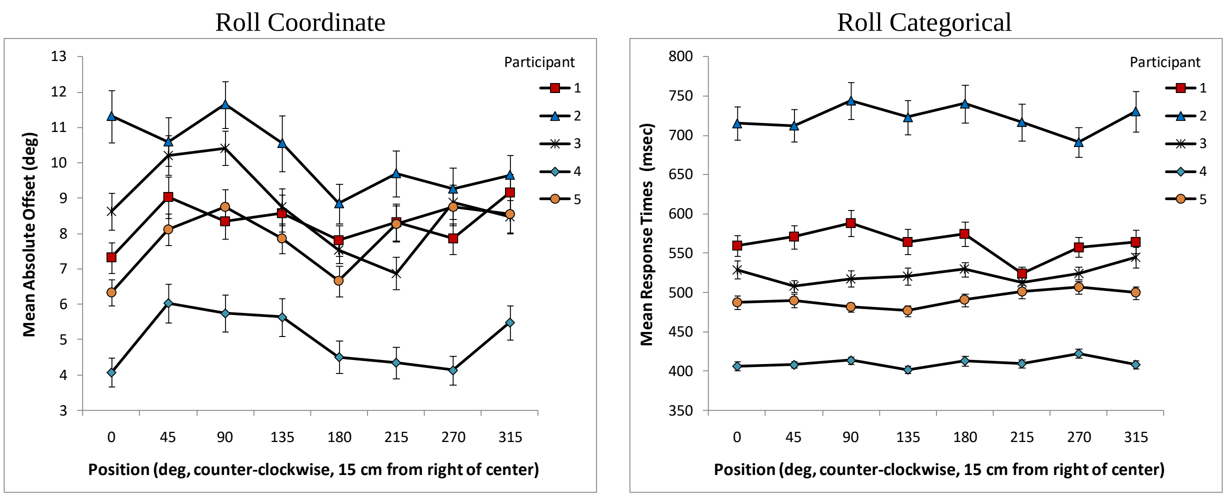


Figure 3. (Left) The mean absolute offsets and (Right) the mean response times across roll directions and angular deviations, at coordinate and categorical trials, respectively, are plotted as a function of the position in the FOV. Errors bars represent ± 1standard error of the mean.

Table1. Results from Friedman and Dunn-Bonferroni post-hoc tests. Assessed at a significance level of α = .05. Effect size, *r*, from Wilcoxon signed-rank tests.

Attitude Parameter	Climb/Dive						Roll					
Task	Coordinate			Categorical			Coordinate			Categorical		
$\chi^2(7)$	21.00			20.47			17.533			9.33		
p -value	**.004**			**.005**			**.014**			.230		
Pairwise Tests		*p-value*	*r*		*p-value*	*r*		*p-value*	*r*			
	180 vs 90	**0.014**	0.64	180 vs 90	**0.002**	0.64	180 vs 90	**0.035**	0.64			
	0 vs 90	**0.014**	0.64	180 vs 270	**0.014**	0.64						

Acknowledgements

We want to thank Dr. Paul Havig for discussions on the subject matter and Mr. David Dommett for software coding of the tasks.

References

Bourne, V. J. (2006). The divided visual field paradigm: Methodological considerations. *11*(4), 373-393. doi:10.1080/13576500600633982.

Bradshaw, J.L. (1990). Methods for Studying Human Laterality. In Boulton A.A., Baker G.B., Hiscock M. (eds.) Neuropsychology. Neuromethods, Vol 17. Human Press, Totowa, N.J. doi.org/10.1385/0-89603-133-0:225.

Brederoo, S. G., Nieuwenstein, M. R., Lorist, M. M., & Cornelissen, F. W. (2017). Brain and Cognition Hemispheric specialization for global and local processing: A direct comparison of linguistic and non-linguistic stimuli. *Brain and Cognition*, *119*(September), 10-16. doi:10.1016/j.bandc.2017.09.005.

Corbett J.E., Carrasco M. (2011) Visual Performance Fields: Frames of Reference. PLoS ONE 6(9): e24470. doi:10.1371/journal.pone.0024470.

Eric E. Geiselman, Paul R. Havig, Michael T. Brewer, "Nondistributed flight reference symbology for helmet-mounted display use during off-boresight viewing: development and evaluation," Proc. SPIE 4021, Helmet-Mounted Displays V, (23 June 2000); doi:10.1117/12.389157.

Jenkins, J.C. (2008). Arc Segment Attitude Reference (ASAR) Head-up Display (HUD) Symbology as a Primary Flight Reference Test and Evaluation. Air Force Flight Test Center, Edwards Air Force Base, California. Air Force Material Command. United States Air Force. Technical Report AFFTC-TR-06-06.

Jewell, G., and McCourt, M.E. Pseudoneglect: a review and meta-analysis of performance factors in line bisection tasks. Neuropsychologia. 38 (1): 93–110. doi:10.1016/s0028-3932(99)00045-7.

Hellige, J.B. (1993). Hemispheric Asymmetry, What's Right and What's Left. Cambridge, MA./ London England, Harvard University Press.

Jager, G., and Postma, A. (2003). On the hemispheric specialization for categorical and coordinate spatial relations: a review of the current evidence. Neuropsychologia 41, 504–515. doi: 10.1016/S0028-3932(02)00086-6.

Kosslyn, S. M., Koenig, O., Barrett, A., Cave, C. B., Tang, J., & Gabrieli, J. D. E. (1989). Evidence for Two Types of Spatial Representations: Hemispheric Specialization for Categorical and Coordinate Relations. *15*(4), 723-735.

Rezaul, Karim, A. K. M., & Kojima, H. (2010). The what and why of perceptual asymmetries in the visual domain. *Advances in Cognitive Psychology, 6*(6), 103-115. doi:10.2478/v10053-008-0080-6.

Thomas, N. A., & Elias, L. J. (2011). Upper and lower visual field differences in perceptual asymmetries. *Brain Research, 1387,* 108-115. doi:10.1016/j.brainres.2011.02.063.