WHEN DAY IS DONE AND SHADOWS FALL, WE MISS THE AIRPORT MOST OF ALL

DR. STANLEY N. ROSCOE
University of Illinois at Urbana-Champaign

ABSTRACT

Both the effectiveness of pilot training and the safety of flight can be influenced by the distribution of texture in the visual scene, the distance to which the eyes accommodate, and the associated shifts in the apparent size and distance of objects in central and peripheral vision. Results to date indicate that these factors are involved in various misjudgments and illusions experienced by pilots: (1) when searching for other airborne traffic or targets, (2) when making approaches to airports over water at night, (3) when breaking out of low clouds on a final approach to a landing by reference to head-up or head-down displays, and (4) when practicing simulated approaches and landings or air-to-surface weapon deliveries by reference to synthetically generated visual systems.

WHAT THIS TALK IS ABOUT

1. Making landing approaches over water on a dark night toward a brightly lighted city.

2. Looking for intruding airplanes from the flight engineer's seat.

3. Sitting inside a screened porch and trying to read a NO FISHING sign down by the lake.

4. Projecting afterimages onto the walls of a football stadium.

5. Watching the moon rise over Miami.

What do these seemingly unrelated activities have in common? And what does all this have to do with head-up flight displays, head-down imaging displays, helmet-mounted displays, and visual systems for contact flight simulators? In each case visual illusions occur: systematic misjudgments of size and distance relationships, departures by varying amounts from the so-called "size-distance invariance hypothesis."

VISUAL ILLUSIONS IN FLIGHT

When pilots make approaches and landings with any type of imaging flight display projected at unity magnification, they tend to come in fast and long, round out high, and touch down hard. On the final approach the runway appears smaller, farther away, and higher in the visual field than it does when viewed directly from the same flight path on a clear day. This finding has been obtained independently both with flight periscopes and with simulated contact visual systems (Roscoe, Hasler, and Dougherty, 1966; Palmer and Cronn, 1975; Roscoe, 1976).

In stark and tragic contrast, when pilots make approaches to landings over water on a dark night toward a brightly lighted city, the runway appears larger, nearer, and lower in the visual field than it does when viewed directly from the same flight path on a clear day. On several occasions in recent years, a commercial airliner has landed in the water short of the airport when making an approach at night. Kraft (1968; 1978) has shown that pilots will systematically misjudge the height and "tilt" of the runway and make low approaches under these conditions.

In another experiment by Kraft, Farrell, and Boucek (1970), a group of pilots judged the threat of midair collision with intruding airplanes at varying distances and angles, none of which represented an actual collision threat. The pilots were presented a series of pictures projected onto a screen viewed from a mocked-up Boeing 737 cab. When the judgments were made from the flight engineer's seat, as opposed to the pilot's seat, the same pilots consistently judged the intruders to be a greater threat at all ranges out to 3500 feet. From the rear seat, the intruders appeared reliably larger and closer than from the front seat.

The viewpoint from the flight engineer's seat is nearly two meters from the windshield aperture; from the pilot's seat it is less than one meter. Furthermore, the view from the flight engineer's seat includes much of the instrument panel when searching for intruders. When searching head-up from the pilot's seat, the instrument panel appears in the dim periphery; the pilot sees mainly empty space through a windshield that reflects glare and may be dirty or scratched. These conditions suggest that pilots may unknowingly be subject to the "Mandelbaum Effect."

In 1960, Mandelbaum reported an informal experiment in which he asked subjects to read a distant sign from a screen-enclosed porch. For each observer he found a critical distance from the screen at which the sign could not be read, although it was clearly legible from other distances, either nearer or farther. Upon questioning, the subjects realized that they could not help focusing on the screen from the critical distance but could readily focus on the sign by moving either nearer or farther from the screen or by quick movements of the head from side to side. Mandelbaum concluded that the "effect" was due to involuntary accommodation.

It was noted that the critical distance from the screen varied from person to person, with an average distance of about one meter. In an ingenious series of experiments at Pennsylvania State University, Owens (in press) has subsequently determined that the critical distance is the distance of the individual's dark focus, or resting accommodation. For the young, healthy eyeball, that distance on average is slightly less than one meter (slightly more than one diopter in optical terms), the distance of the dirty windshield from the pilot. Almost any textured visual stimulus at that distance is a powerful involuntary "accommodation trap."

A SCIENTIFIC MYSTERY

In addition to the misjudgments of size and distance discussed so far, bias errors in depth discrimination have been discovered independently by designers of submarine periscopes, tank periscopes, laboratory microscopes, "one-power" scopes for shotguns, and helmet-mounted CRT displays. All require some optical magnification to cause objects to appear at the same distances as when viewed by the naked eye. Furthermore, all involve reductions in the field of view and in the textural gradient that serves as the stimulus for distant accommodation. These biased perceptions of size and distance are not fully explained, at least not sufficiently to give comfort to the pilots and passengers of airplanes.

The mystery manifests itself in many forms that have puzzled psychologists from Ptolemy who tried to explain the "moon illusion" to Young (1952) who had subjects project visual afterimages onto the walls of the Ohio State football stadium from various distances across an open field. The farther the afterimage is projected, the larger it appears, but not in direct proportion as would be predicted by the size-distance invariance hypothesis. The "size" of the moon also varies with the extent of the visible textural gradient, appearing larger over a distant horizon than it does over a near horizon, as shown by Kaufman and Rock (1962).

Throughout the literature of vision research may be found additional examples of unexplained experimental findings and assorted "optical illusions" that may be related to the observations by Wheatstone (1852) and Helmholtz (1867/1962), and more recently verified experimentally by Biersdorf and Baird (1966), by Leibowitz, Shiina, and Hennessy (1972), and by Roscoe, Olzak, and Randle (1976), that the apparent size of an object changes with shifts in the distance to which the eye is accommodated. The phenomenon can be illustrated by any one of several simple experiments.

For example: close one eye, focus your open eye on your thumb held at arm's length, observe a more distant object such as a window or a picture on the wall, and while continuing to focus on your thumb, draw it toward you and observe the change in the size of the window or picture. Better yet: look at the moon through a peekhole through your fist, alternately closing and opening the other eye. Not only can the moon on the horizon be made to appear smaller, but also the moon overhead can be made to vary in apparent size by a surprising amount.

INVESTIGATING THE MYSTERY

To investigate the possibility that shifts in apparent size are associated with shifts in visual accommodation distance, an experiment was conducted at NASA's Ames Research Center in which visual accommodation was measured continuously, using a Crane-Cornsweet infrared optometer, while subjects viewed discs that subtended a constant 3° angle at distances ranging from 1/4 to 4 meters, with and without the distance cues provided by a sometimes visible textural gradient (Roscoe, et al., 1976). Shifts from binocular to monocular viewing were accompanied by shifts in accommodation, both inward and outward, toward an intermediate distance of a little less than one meter (1.13 diopters, on average).

The reliable inward shifts from the most distant targets at 4 meters were accompanied by reliable reductions in apparent size. A contingency analysis, summarized in Table 1,

TABLE 1.

SUMMARY OF CONTINGENT PROBABILITY ANALYSIS OF PREDICTED JUDGMENTS OF RELATIVE SIZE WITH CORRESPONDING SHIFTS IN ACCOMMODATION (CHANCE PROBABILITY OF CONTINGENCY = 0.25).

	DISTANCE TO TARGET, METERS			
	1	1-1/2	2	4
CHANCE CONTINGENCY	.25	.25	.25	.25
OBSERVED CONTINGENCY	.23	.36	.38	.45
Chi^2	___	7.59	11.34	25.01
p	n.r.	<.01	<.002	<.001

showed that the correlation between shifts in apparent size and shifts toward the resting accommodation distances of the individual subjects increased with target distance. At one meter there was a chance relationship, at 1 1/2 meters the contingency was reliable at the p <.01 level, at two and four meters the p values were < .002 and < .001, respectively. At four meters the contingency was almost 2 to 1 greater than chance, which shows a highly likely relationship but still leaves a lot of variance unaccounted for.

To clarify the relationship between accommodation and apparent size, 12 of the original 16 subjects were tested on near (1/4-meter) and far (4-meter) targets with a 1-mm diameter artificial pupil placed 8 cm from the entrance plane of the eye used for monocular viewing. An artificial pupil allows the eye to lapse farther toward its resting position without causing a blurred image (Hennessy and Leibowitz, 1975). In binocular viewing the second eye was unobstructed, thereby requiring more accurate accommodation to obtain a clear image of the target. The results of this comparison are shown in Table 2.

The arrows in Table 2 indicate the shifts in accommodation toward the resting position from binocular to monocular viewing, and the plus-signs indicate coincidence of positive accommodation shifts and "Monocular Smaller" judgments, or conversely, negative accommodation shifts and "Monocular Larger" judgments. The introduction of the artificial pupil clarifies the relationship: for the 4-meter target, the coincidence is virtually perfect, 23 of 24 cases in agreement; for the 1/4-meter target, accommodation shifted in the predicted direction 9 times in 12 under both light and dark ambient illumination, but only in the dark is there evidence of a trend toward "Monocular Larger"

TABLE 2.

SHIFTS IN MEASURED VISUAL ACCOMMODATION AND JUDGMENTS OF THE RELATIVE SIZE OF THREE-DEGREE DISCS, VIEWED MONOCULARLY (M) AND BINOCULARLY (B) AT DISTANCES OF 25 CM (4.00 DIOPTERS) AND 4 M (0.25 DIOPTER) UNDER NORMAL ROOM LIGHTING (LIGHT) AND REDUCED ILLUMINATION (DARK), WITH AN ARTIFICIAL PUPIL IN FRONT OF THE LEFT (MONOCULAR) EYE.

	Distance to Target Disc							
	25 cm (4.00 diopters)				4 m (0.25 diopter)			
	Dark		Light		Light		Dark	
S	B	M	B	M	M	B	M	B
1	2.64 →	2.07 +	3.07 →	2.27 +	0.69 ←	0.24 +	1.18 ←	0.28 +
2	3.70 →	2.81 +	3.88 →	2.50	1.06 ←	0.32 +	0.12 ←	-0.43
3	3.86 →	2.86 +	4.42 →	1.78 +	0.87 ←	0.26 +	-0.21 ←	-0.78 +
4	0.26 →	0.17	0.49	0.79	-0.15 ←	-0.67 +	-0.58 ←	-0.97 +
5	1.86 →	1.51	2.18 →	1.06	-0.12 ←	-0.61 +	0.17 ←	-0.33 +
6	4.13 →	2.86	4.40 →	3.38	0.07 ←	-0.14 +	0.53 ←	-0.56 +
7	3.04 →	1.76 +	3.75 →	2.14	1.02 ←	0.68 +	0.63 ←	0.39 +
8	4.30 →	2.66 +	4.66 →	4.12 +	0.26 ←	-0.11 +	-0.10 ←	-0.54 +
9	2.18 →	1.83 +	1.71 →	1.07 +	-0.13 ←	-1.02 +	-0.08 ←	-0.84 +
10	3.13 →	1.94 +	3.95 →	3.15 +	0.58 ←	0.06 +	0.22 ←	0.02 +
11	2.58 →	2.24 +	3.12 →	2.51	1.73 ←	0.35 +	1.25 ←	0.45 +
12	3.32 →	1.98 +	3.08 →	1.54 +	0.18 ←	0.05 +	-0.33 ←	-0.41 +
Mean	2.92	2.06	3.23	2.19	0.51	-0.05	0.23	-0.31

Legend: Arrow indicates that shift from binocular to monocular accommodation is toward intermediate distance. + indicates that a positive shift in accommodation is accompanied by a judgment of "Monocular Smaller" or, conversely, a negative shift by "Monocular Larger."

judgments with outward shifts in accommodation (9 of 12 cases, $p < .10$).

In addition to the fact that correlations do not guarantee causal relationships, these findings are equivocal because of the confounding of shifts in accommodation, which were measured, with shifts in convergence between binocular and monocular viewing, which were not measured. Furthermore, the accommodation data are not sufficiently clean for comfort, and a few individual data are suspect by inspection. Nevertheless, neither the data nor their implications can be discounted as completely spurious in the absence of better data. In any case, the mystery is not so much how we judge the size and distance of near objects that afford binocular cues as it is how we judge distant objects that provide only monocular cues.

To gain a better understanding of the effects of visual accommodation upon judgments in tasks involving complex, dynamic visual scenes, another experiment was recently conducted at Ames Research Center using the Crane-Cornsweet infrared optometer and an experimental night-landing visual display generated by a digital computer (Randle, Roscoe, and Petitt, in press). Professional pilots made judgments of whether they would undershoot or overshoot their landing aimpoint as the computer flew their simulated jet transport on final approaches to the computer-generated airport scene.

Experimental variables included: (1) the magnification of the visual scene, which was varied in five steps between 0.83 and 1.67, (2) the visual accommodation distance induced by five sets of ophthalmic lenses with dioptric powers ranging from zero to three, (3) the actual descent path of the simulated airplane, which included overshoots and undershoots as well as correct landing approaches, and finally, (4) whether the landing scene was presented as a real image viewed directly on a TV monitor or a virtual image produced by a collimating field lens mounted between the monitor and the pilot.

The first finding was that the eye does not respond obediently to the accommodation distances called for by ophthalmic lenses; the eye is lazy and reluctant to be drawn away from its intermediate resting position. The brain, in turn, seems happy to accept an amazingly out-of-focus image uncritically and, in fact, without conscious recognition that it is out of focus. In response to ophthalmic lenses covering the range from zero to three diopters, the pilots' eyes, on average, accommodated to the virtual and real images over ranges of only 1.27 and 1.46 D, respectively.

Despite the relatively small shifts in accommodation "induced" by the ophthalmic lenses, there were statistically reliable interactions in the predicted directions between actual accommodation levels and the pilots' judgments of whether they would overshoot or undershoot their landings. There is now little doubt that such judgments are related in some complicated way to visual accommodation distance, which, in turn, is affected far more by the various viewing conditions encountered in the spectrum of normal flight operations than it was by the ophthalmic lenses used.

An experiment typically raises more questions than it answers, and this one was no exception. The pilots made two judgments along the final approach, the first at 20 seconds, or 4000 feet, before passing the runway aimpoint and the second at 10 seconds, or 2000 feet. With unity image magnification, they predominantly indicated an overshoot on the first judgment and an undershoot on the second. If they had been flying manually, they would have tended to overshoot. Veridical judgments were obtained at the nearer distance with an image magnification of 1.25, as has been found with flight periscopes (Roscoe, et al., 1966).

The possible explanations for this curious reversal in judgments are infinite. Of course, the finding might be unique to the particular computer-generated night visual scene used. However, based in Kraft's findings, it could be that pilots habitually make low approaches at night to avoid overshooting and, when they are still 4000 feet out, "expect" the runway to appear as it does from a position below the 3-degree approach path. At 2000 feet out, they can see their position better and maintain thrust to carry them to the touchdown.

At 4000 feet out the dominant cues for accommodation, namely, the airport lighting system and the lighted city beyond, appear as a thin horizontal band of point sources at a relatively great distance; far accommodation is required to resolve the scene. As the airplane approaches the runway, the band deepens and comes nearer; the runway lights are more easily resolved, and accommodation drifts inward from its distant "trap." The so-called "size constancy" of the runway is not maintained; in effect it shrinks a little, and pilots tend to overshoot their aimpoint once they have safely crossed the threshold.

To test this wild speculation, two experiments have just been conducted at the University of Illinois (Iavecchia, 1978). A 1/2-degree collimated disc of light, simulating the moon, was projected onto a 45-degree combining glass so that it appeared as a virtual image superposed on the outside visual scene (a la Kaufman and Rock). A second, comparison "moon" of adjustable diameter was presented as a real image at a distance of one meter in an otherwise dark surrounding. The two views were presented alternately in the same visual position by means of a sliding mirror arrangement, and the subject adjusted the diameter of the comparison until a satisfactory apparent-size match was obtained.

In the first experiment, conducted in clear daylight, subjects viewed the collimated moon against the scene visible from corresponding windows of the third to the eighth floors of the Psychology Building overlooking the Urbana campus and residential area. On the third floor the moon was projected against the roof of a nearby sorority house, and on successively higher floors against successively more distant rooftops and large trees. At the fifth and sixth floors it appeared just above the horizon, and on the seventh and eighth, higher and higher above the horizon. The apparent size of the moon increased from the third to the sixth floors and then reversed itself as it rose above the horizon.

The mean apparent size ratios of the moon, relative to its apparent size when projected onto a newspaper viewed from one meter, were (3rd floor) 1.143, (4th) 1.250, (5th) 1.311, (6th) 1.364, (7th) 1.330, (8th) 1.282. These means differed reliably ($p < .05$). As the moon was projected against increasingly distant surfaces from the 3rd through the 6th floors, its apparent size increased monotonically. From the 6th floor, the moon was projected against the sky just above the most distant surface texture. From the 7th and 8th floors, it was projected against the sky higher and higher above the horizon.

In the second experiment the distance and vertical position of visible texture was manipulated more systematically by viewing the scene from the fifth floor through a series of masks. Four of the masks revealed horizontal bands of texture in the Near, Intermediate, Far, and Very Far visual fields. Another mask obscured all surface texture in the visual field so that the moon was projected against the open sky just above the "horizon" formed by the mask. Finally, a clear mask revealed the entire scene. The results of these tests clarify the situation.

When viewing the moon against the "unmasked" background scene (clear-mask control condition), its apparent size ratio was 1.369. With the mask that revealed only Near texture, it was 1.225; for Intermediate texture, 1.235; for Far texture, 1.289; and for Very Far texture, 1.395. With the mask that obscured all surface texture below the horizon (similar to a view of the moon overhead), the apparent size ratio dropped abruptly to 1.136, only slightly larger than its apparent size when projected onto the newspaper viewed from a distance of one meter.

What these two experiments show is that the apparent size of objects well beyond the 6-meter, or 20-foot, distance to "optical infinity" change reliably with changes in the spatial distribution of textural stimuli to accommodation in the background visual scene. The greater the distance through empty space to resolvable texture, the larger the apparent size of centrally fixated objects, such as the moon or an airport runway. As the textural pattern extends downward or moves nearer, the central object fails to maintain a constant "apparent size." As the pilot approaches a runway over water at night, his visual image of the runway grows, but not in perfectly inverse proportion to distance remaining.

When no resolvable background texture is present, as when viewing the moon against a clear sky, the textureless moon provides an inadequate stimulus to distant accommodation and shrinks in size, as do the symbols of a head-up display when flying in clouds. Even a partially clouded sky apparently cannot hold distant accommodation to a textureless collimated moon or display symbols. Thus, the "moon illusion" is not manifested by a spuriously large moon on the horizon but rather by a perceptually shrunken moon overhead.

IMPLICATIONS FOR FLIGHT SAFETY

For years Kraft, Hennessy, and several other investigators have recommended that pilots routinely wear bifocal lenses at night and when making IFR approaches in daylight conditions. The lower section would optimize their vision for instrument panel and chart viewing distances. The upper section would provide negative correction to aid distant accommodation for outside viewing. Owens and Leibowitz (1976) have shown that, if night drivers with normal vision are asked to select the lenses that allow them to see best, they will choose those with a negative correction halfway between their dark focus and optical infinity.

To combat the possible underaccommodation experienced by some pilots while making "black hole" approaches over water at night, lead-in light buoys should be considered and tested for use at major airports. Although no specific data are available, it would be expected that, in the absence of visible texture in the near field, pilots with extremely distant dark focus would be the ones who tend to make low approaches at night and occasionally land in the ocean.

Perhaps they should wear positive corrective lenses at night, but evidently no such tests have been made.

The use of head-up displays for night and IFR approaches warrants further investigation. It has been tacitly assumed and strongly asserted by the advocates of such displays that the collimated presentation prepares the eyes to resolve immediately *whatever is out there to be seen.* Available experimental evidence does not support that assertion. The CIG/NVS landing approach study at Ames (Randle, et al.) and the moon-illusion studies at Illinois (Iavecchia) clearly show that collimating bold, well defined symbology, whether viewed directly or reflected from a combining glass, does not necessarily call the eyes to a far accommodation distance. When the pilot breaks out of the clouds, rapid negative accommodation is required, and the scene "explodes."

IMPLICATIONS FOR PILOT SELECTION AND TRAINING

The evidence presented suggests that dark focus, or resting accommodation distance, in addition to basic visual acuity and color vision, should be taken into account in pilot selection and assignment. Having a far resting accommodation distance might be one basis for assigning military pilots to air combat duty; they should be less troubled by empty-field myopia. Those with a nearer resting position might benefit from negative lenses, as in the case of civilian pilots watching for intruders. As pilots get older their resting accommodation may retreat into the distance, occasionally to a point at which they could have serious problems making "black hole" approaches.

There is ample empirical evidence that pilots learn to compensate for the biased distance judgments they experience at night and with flight periscopes and the visual systems used in flight simulators. Specific training in the relationships between viewing conditions and the direction and magnitude of the associated visual biases would expedite learning the appropriate compensations. Providing variable magnification in computer-generated night visual systems as a function of the variations in visibility and illumination simulated would give the manufacturer another training feature to sell--one that might be worth its cost.

ACKNOWLEDGMENT

The original research upon which this paper is based was sponsored by the Ames Research Center, NASA, with Robert J. Randle as Scientific Monitor, and by the Air Force Office of Scientific Research, AFSC, with Dr. Alfred R. Fregly as Scientific Monitor. Technical review of the experimental plans for the AFOSR studies was provided by scientists from the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Oskar F. Richter, Department of Psychology, University of Illinois at Urbana-Champaign, designed and constructed the apparatus used in the AFOSR moon-illusion experiments. Scientific consultation was provided by Dr. Robert T. Hennessy of the Canyon Research Group, by Patrick FitzHenry of Illiana Aviation Sciences, and without recompense, by Robert J. Randle of the Ames Research Center. Morris H. Maitland prepared all graphic materials for the Illinois experiments and for this report.

The experiments at the Ames Research Center were conducted by Lynn A. Olzak and John Petitt of the Hughes Aircraft Company and by Donna Miller of the Ames Research Center. The experiments at the University of Illinois were conducted by Graduate Research Assistants Joyce H. Iavecchia and Helene P. Iavecchia. Kathleen J. Beringer typed the manuscript.

REFERENCES

Biersdorf, W.R. and Baird, J.C. Effects of an artificial pupil and accommodation on retinal image size. Journal of the Optical Society of America, 1966, 56, 1123-1129.

Helmholtz, H. von. Physiological optics. New York: Dover, 1867/1962.

Iavecchia, J.H. Masters thesis in preparation, 1978.

Kraft, C.L. and Elworth, C.L. How high is up? Interceptor, 1968, 10(10), 4-14.

Kraft, C.L. A psychophysical contribution to air safety: simulator studies of visual illusions in night visual approaches. In H.A. Pick, Jr. (Ed.) Psychology: From research to practice. New York: Plenum, 1978

Owens, D.A. and Leibowitz, H.W. Night myopia: Cause and a possible basis for amelioration. American Journal of Optometry and Physiological Optics, 1976, 53, 709-717.

Kraft, C.L., Farrell, R.J., and Boucek, G.P., Jr. Visual performance from the 737 cab as a function of pilots position within the cab. Seattle, WA: The Boeing Company, Unpublished internal report, 1970.

Leibowitz, H.W., Shiina, K., and Hennessy, R.T. Oculomotor adjustments and size constancy. Perception and Psychophysics, 1972, 12, 497-500.

Mandelbaum, J. An accommodation phenomenon. American Medical Association Archives of Ophthalmology, 1960, 63, 923-26.

Owens, D.A. The Mandelbaum effect: Evidence for an accommodative bias toward intermediate viewing distances. Journal of the Optical Society of America, in press.

Palmer, E. and Cronn, F.W. Touchdown performance with a computer graphics night visual attachment. Proceedings of the AIAA visual and motion simulation conference. New York: Institute of Aeronautics and Astronautics, 1973.

Randle, R.J., Roscoe, S.N., and Petitt, J. Effects of accommodation and magnification on aimpoint estimation in a simulated landing task. Washington, D.C.: National Aeronautics and Space Administration, Technical Note (in press).

Roscoe, S.N. How big the moon, how fat the eye? Urbana, IL: University of Illinois at Urbana-Champaign, Aviation Research Laboratory, Technical Report ARL-77-9/AFOSR-77-8, 1977.

Roscoe, S.N., Hasler, S.G., and Dougherty, D.J. Flight by periscope: Making takeoffs and landings; the influence of image magnification, practice, and various conditions of flight. Human Factors, 1966, 8, 13-40. [Originally issued in 1952 by the Office of Naval Research as Human Engineering Report SDC 71-16-9.]

Roscoe, S.N., Olzak, L.A., and Randle, R.J. Ground-referenced visual orientation with imaging displays: Monocular versus binocular accommodation and judgments of relative size. Proceedings of the AGARD Aerospace Medical Panel specialists meeting, Athens, Greece. Nuilly-sur-Seine, France: North Atlantic Treaty Organization, 1976.

Wheatstone, C. The Bakerian lecture: Contributions to the physiology of vision: Part the second. On some remarkable, and hitherto unobserved, phenomena of binocular vision (continued). Philosophical Magazine (Series 4), 1852, 3, 504-523.

Young, F.A. Studies of the projected afterimages: III. The projection over large distances. Journal of General Psychology, 1952, 47, 207-212.

ABOUT THE AUTHOR

DR. STANLEY N. ROSCOE is the associate director for research of the Institute of Aviation and professor of aviation, aeronautical and astronautical engineering, and psychology, University of Illinois at Urbana-Champaign. He received his PH.D. in experimental (engineering) psychology from the University of Illinois in 1950. From 1943 to 1946 he served as a pilot instructor and transport pilot in the United States Army Air Corps. From 1946 to 1952 he was successively a research assistant, research associate, and assistant professor at the Aviation Psychology Laboratory, University of Illinois, where he conducted research on flight display principles. In 1952 he joined Hughes Aircraft Company where he established a human factors research and development program. He was manager of the display systems department at the time of his return to the University of Illinois in 1969. The Aviation Research Laboratory at the university airport now supports a research staff of approximately 50, including about 25 graduate research assistants, who perform contract research for the Air Force Office of Scientific Research, the Air Force Avionics Laboratory, the Office of Naval Research, the Federal Aviation Administration, and the Link Foundation. He is a past president of the Human Factors Society (1960-1961) and was a member of the executive council continuously between 1959 and 1971. He received the Society's Jerome H. Ely award for the best article published in Human Factors in 1968 and again in 1972. He also received the Society's Alexander C. Williams, Jr. award in 1973 for his contribution to the design of the Convair F-106/Hughes MA-1 aircraft and weapon control system. In 1969 he was cited by the Radio Technical Commission for Aeronautics for his contributions to the advancement of airborne area navigation as Chairman of RTCA Special Committee SC-116E. He is a technical advisor to that organization and to the National Aeronautics and Space Administration.