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APPARENT SIZE AND VISUAL ACCOMMODATION UNDER DAY AND NIGHT COND--ETC(U)

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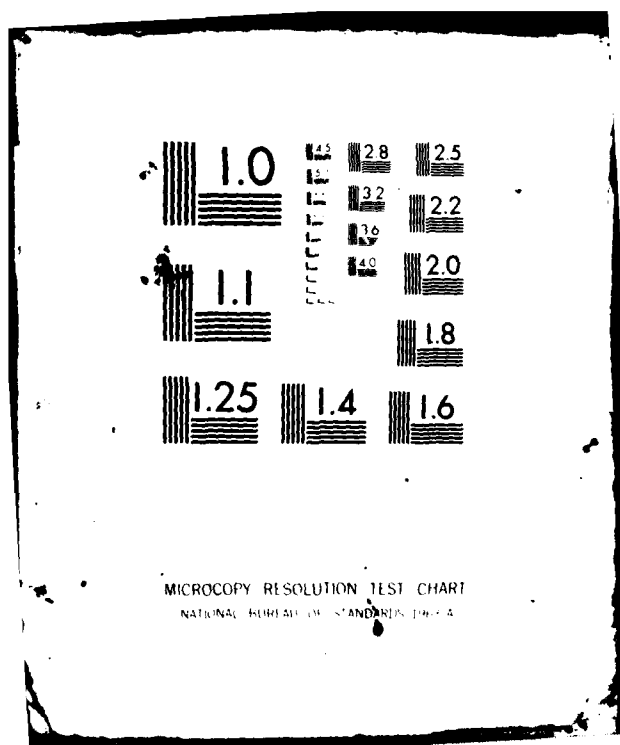
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Six subjects on a building roof viewed the outside terrain through a projection device which superposed a full horizon moon on that view. Subjects judged the size of the moon in various scenery configurations by adjusting a comparison disc while accommodation measurements were taken using a laser optometer. Results showed a strong correlation between mean accommodative states and size judgments during the day and a weaker correlation at night. Accommodation responses were not identical to all scenes and as accommodation shifted inward, the judged size of the moon decreased. "Night myopia" was also clearly evident. The relatively		

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✓ nearer accommodation responses and smaller size judgments of the isolated zenith-type moon as compared to the horizon moon suggests that the moon illusion is mediated by the accommodation mechanism. The results are discussed in connection with a similar study by Iavecchia, Iavecchia and Roscoe, and differences in the mean "dark focus" of accommodation between the two groups are related to the findings.

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**APPARENT SIZE AND
VISUAL ACCOMMODATION UNDER
DAY AND NIGHT CONDITIONS**

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INTRODUCTION

The relationship between apparent size and various oculomotor functions has been the object of long-standing psychophysical investigation, but objective, unobtrusive measurement of responses such as accommodation has been difficult. However, with the use of the infrared and laser optometers in recent years, the refractive state of the eye has become easier to measure and is a dependent variable of increasing interest. Several ongoing investigations are concerned with the covariance of accommodation and apparent size and distance. The present experiments are part of one such project.

Past speculation as to the effects of accommodation on retinal image size, and presumably the concomitant perceived size, has run the full spectrum: larger image, smaller image, no change. Proprioceptive feedback, innate neurophysiology, and learned behavior have all been implicated in the well-known size/distance constancies and related ocular phenomena. It is becoming increasingly clear, however, that simpler classical views of visual behavior are inadequate to describe recently well-documented phenomena. The search for explanations of certain visual illusions has turned, in part, to the action of accommodation.

Studies of the "resting state" of accommodation and the "anomalous myopias" (Leibowitz and Owens, 1978), and of the "Mandelbaum effect" (Owens, 1979) have lead to a redefinition of "normal" vision. In particular, the "resting state" of accommodation is known to be nearer than the optical infinity which had been accepted from Helmholtz' time. This "dark focus" is the refractive state to which the eye has a tendency to return in the absence of resolvable stimuli. It has been well demonstrated that, for most people, it is at arm's length or less and exerts a "pull" towards its position.

Accommodation may be thought of as a compromise between the pull toward the resting state and pull toward the stimulus, the latter being usually much stronger under normal viewing conditions. Investigations involving the dark focus have shown maximum focusing accuracy at this point, and resulting maximum acuity and sensitivity (Johnson, 1976). It is believed that the pull of the dark focus is also influential in size/distance perception, in that it affects the accommodative state, which, in turn, influences such perceptions.

Iavecchia, Iavecchia, and Roscoe (1978) used a unique projection device in several experiments aimed at examining the objective and subjective reactions to outdoor scenes containing a full "moon" (see Figure 1). The experiments shed light on the moon illusion itself as well as on the behavior of the human lens. In their experiments they found that the standard optometric consideration of 6 m as "optical infinity" obscures the fact that accommodative changes to stimuli well beyond that point may occur.

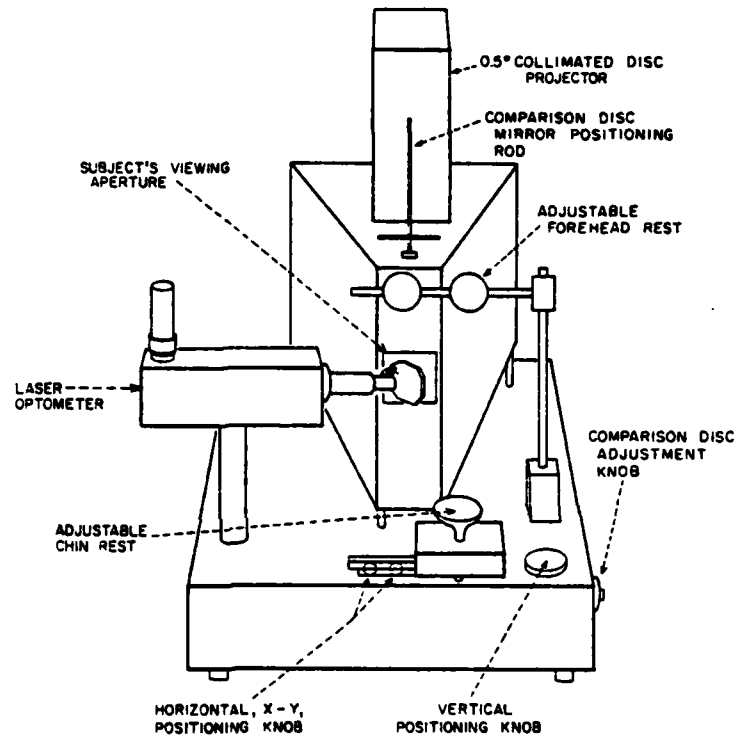


Figure 1. Schematic of the projection/viewing device used to create the moon scenes in this experiment and the Iavecchia, et al. experiment.

Terrain containing the "moon" viewed through the projection device was selectively occluded ("masked") allowing views of near, intermediate, far, and very far scenery, as well as views of fully exposed and completely masked terrain. They found that further and further views elicited increasingly distant accommodation responses which were paralleled by increasingly large size judgments of the moon disc. The smallest size judgment was obtained against a background of a newspaper at 1 m, the nearest stimulus used in their study.

Moreover, accommodation to the moon disc viewed alone in darkness, which is similar to the visual background of the zenith moon, correlated highly (0.95) with the dark focus. Mean accommodative response was only slightly further out (0.28 diopters, see definition below) than the mean dark focus (0.38 D), even though the moon is a stimulus focused at optical infinity (0 D). This indicates that the zenith and horizon moons are reacted to quite differently at times. The background against which the zenith moon appears provides a relatively weak stimulus to distant accommodation.

METHOD

Subjects

Subjects were six university undergraduate volunteers, three male and three female, ranging in age from 19 to 22. They were neither paid for their participation nor given any course credit.

Apparatus

The apparatus is the same used in the Iavecchia, et al. study. It is essentially an enclosure through which an observer may view the outside terrain, or any other visual configuration. A 0.67-degree collimated disc, slightly larger than the 0.5-degree full moon, may be superposed on that view. Alternately, a similar subject-adjustable, variable-diameter disc may be brought into view (which completely replaces the viewed scene) allowing a variety of size judgment experiments to be arranged.

The six masks used in the Iavecchia study were also used in this experiment. They are identified as follows: (AL) all terrain fully exposed, no occlusions; (NR) only near terrain exposed; (IN) only intermediate terrain; (FR) only far terrain; (VF) only very far terrain; (NO) no terrain exposed. In every case, the portion of the view from the horizon upwards was in full view and the moon was projected just above the horizon.

Additionally, the device can accept any of several instruments for measuring the accommodative state of the viewing eye. In this experiment, as in the Iavecchia study, accommodation was measured with a laser optometer similar to that described by Leibowitz and Hennessy (1975).

Procedure

The apparatus was placed on the roof (35 m above street level) of the eight-story psychology building at the University of Illinois and directed at the distant horizon toward the north-west. Within view were a distant interstate highway, a downtown business area, a residential area, and interspersed parks and greenery. All the visible terrain was more distant than in the Iavecchia, et al. study where the "near" stimulus was the roof of a building at 30 m. Subjects were seated at the apparatus and asked to make size judgments of the moon on the horizon while various portions of the visual field were masked. At the same time, their accommodation was measured with the laser optometer.

The entire procedure was conducted in clear daylight between 1 and 3 PM on a day in late October and again between 8 and 11 PM with the same subjects. All subjects made size judgments by alternately viewing the horizon moon scene and then the comparison disc. Subjects were allowed as many views of both discs as they needed to make size matches. Each subject made four consecutive size judgments to one mask before moving on to the next mask. Order of mask presentation was counterbalanced so that each mask was preceded and followed once by every other mask. One accommodation reading was taken to each mask scene after the fourth size judgment.

RESULTS AND DISCUSSION

The daytime accommodation means are based on measurements for four of the six subjects. Accommodation data were not obtained for the first two subjects in the afternoon session as the laser in the optometer initially malfunctioned. All the night accommodation data and all the day and night size judgment data were obtained as were dark focuses for all subjects.

Among the findings was a not-surprising demonstration of "night myopia." Mean accommodation responses to the various views, without exception, were more myopic (nearsighted) at night than during the day. Another finding was the high correlation during the day (0.94) between mean accommodative states and size judgments. This matches the 0.89 correlation from corresponding data in the Iavecchia experiment. In both studies as accommodation shifted further inward, the judged size of the moon decreased. At night, the relationship was not as strong (0.70), the range of accommodation responses being smaller and more myopic. The size judgment and accommodation data are listed in Table 1.

Table 1

Mean Accommodation Responses (Diopters) and Size Judgments (Degrees) to the Six Masks during Day (D) and Night (N) Conditions.

Mask	NR	IN	FR	VF	NO	AL
Size D (N=4)	.93	.88	.86	.95	.88	.97
Acc. D	.53	.63	.78	.53	.73	.48
Size N (N=6)	.84	.87	.82	.92	.87	.91
Acc. N	.97	1.02	1.00	.78	.82	.88
Iavecchia, et al.						
Size D (N=6)	.77	.79	.85	1.05	.80	1.00
Acc. D	.49	.28	.08	-.27	.36	.09

Of additional interest is the fact that the correlation between accommodative shifts from the dark focus and size judgments was as high (day = 0.94, night = 0.72) as that of absolute accommodative state and size judgment just mentioned. That is, not only did the judgments decrease as accommodation came inward, they decreased with approach

toward the subjects' dark focus. This is illustrated in Figure 2. Shifts were calculated by subtracting the subject's accommodative response from his dark focus. A shift of 1.0, for example, could indicate a dark focus of 1.5 and a response of 0.5 D. Shifts simply indicate how close a response is to the subject's dark focus.

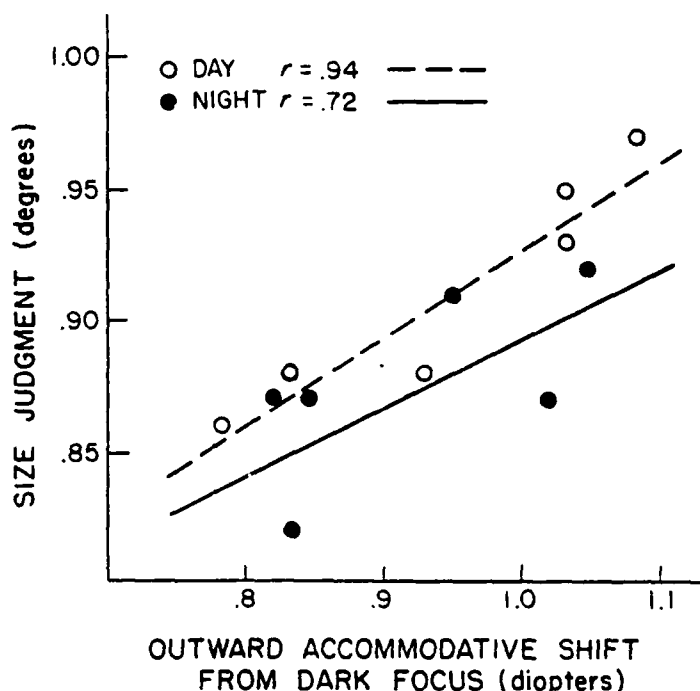


Figure 2. Mean size judgments of horizon moon against various backgrounds as a function of the mean difference between the accommodative response and the dark focus ("shift").

Another effect of the dark focus is seen in size judgments of the moon disc alone in darkness. As mentioned previously, subjects respond to this stimulus by accommodating marginally outward from their dark focuses. In the Iavecchia study, the six subjects happened to be relatively hyperopic as a group. Their mean dark focus was 0.38 D. To the moon disc alone, the mean accommodation was 0.28 D, and the moon's mean apparent size was 0.79 degrees (visual angle subtended by the subject-adjusted comparison disc). Here, with a different group of subjects who happened to be more myopic, the mean dark focus was a much nearer 2.22 D, accommodation to the moon disc was 1.74 D, and the average size judgment was 0.66 degrees.

In this study, as just indicated, there was a nearer mean accommodation response to the moon and a smaller (more veridical) judged size than observed by Iavecchia, et al. Furthermore, for five of the subjects in this study, the correlation between dark focuses and size estimates of the moon disc was 0.90. This is illustrated in Figure 3. The sixth subject did not return for measurement of her responses to the moon disc. The large absolute differences between the two groups in both apparent size and accommodation are direct reflections of the large difference in dark focus.

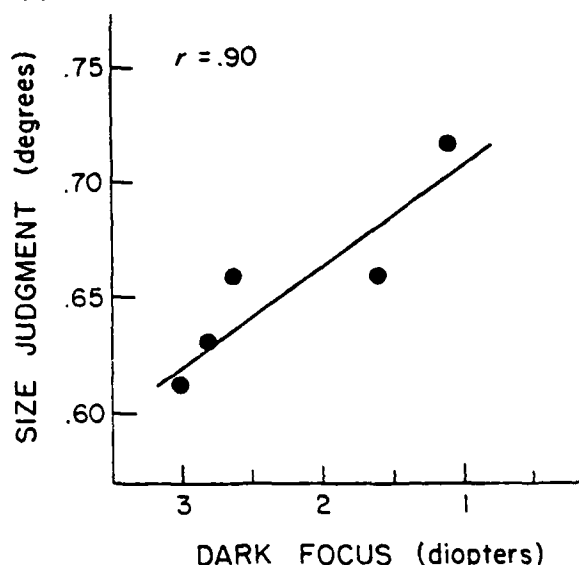


Figure 3. Size judgments of moon disc alone in darkness as a function of dark focus for five individuals.

Figure 4, likewise illustrates that the range of accommodation found in the two studies differed greatly. As can be seen in the accommodation data for masks NR through VF in Table 1, in the Iavecchia study, the "near" condition elicited a mean response of 0.49 D, the "very far" condition, -0.27 D. This is a wide range of fairly orderly responses to the various scenes. In this study, responses varied only from 0.78 to 0.53 D, and the responses to the NR, IN, FR, and VF masks did not form an orderly progression. That is, in the Iavecchia study, the accommodative responses were progressively further out from the near through very far views. Here, the nearest response was obtained to the "far" condition and one of the furthest responses to the "near" condition.

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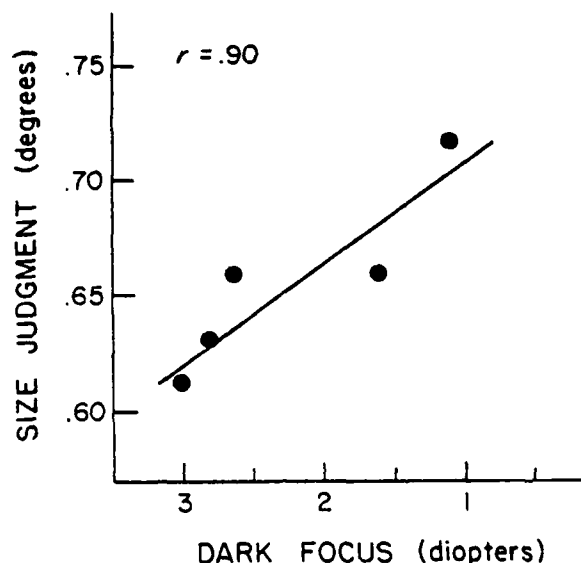


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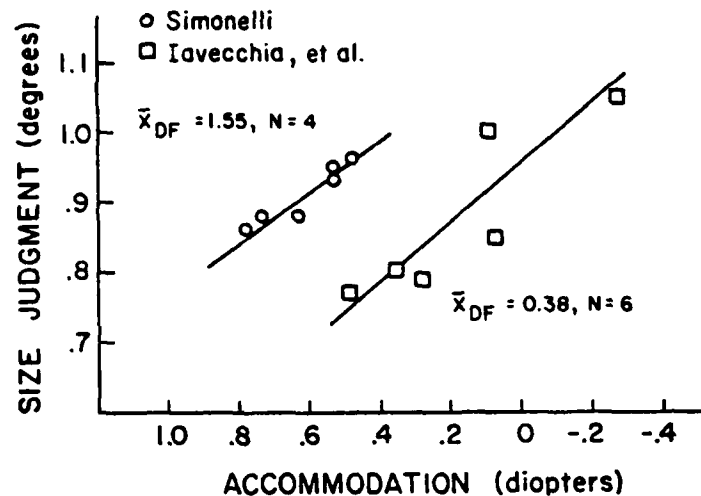


Figure 4. Apparent size of moon as a function of visual accommodation to six scenes for two groups with widely differing mean dark focuses (data taken from Table 1).

The differences between the two sets of results may depend in some complex way on the different outdoor views used. The compositions of the scenes were not identical, and it is not certain exactly which elements in the terrain were responded to. Prominent nearby objects may serve as more effective stimuli to distant accommodation than comparatively textureless far scenes.

In the Iavecchia experiment, conducted through an east window on the sixth floor, the near scene included the shingled roof of a large, prominent house about 30 m distant. Successive scenes were, of course, further away, but there were still prominent buildings in each. The "very far" scene was actually dominated by a large building approximately 410 m distant. That is, the distant view was not a definitionless, hazy blur as is sometimes found at the horizon, but rather a sharply defined building less than one-half km from the observer. These well-defined stimuli correspond to the progressively distant accommodation levels elicited.

In this study, from the roof of the same building but looking toward the north-west, the near scene was dominated by a parking structure at about 125 m. Successive scenes contained mostly trees with occasional buildings. The "far" and "very far" scenes shared a narrow band of structures in the downtown business area, but the distance to that area (1.2 km) left the structures with much less resolvable

detail than Iavecchia's far scene. Apparently, the near scene here provided a better distant stimulus than the further, less detailed scenes, as is evidenced by the inward progression of the mean accommodative responses. However, a systematic manipulation of stimuli would be necessary to define such a relationship.

A final observation of interest is the response to the "very far," "no-terrain," and "all-terrain" conditions. The "very far" view elicited the most distant accommodation response in the Iavecchia study and very nearly so in this study (only the accommodation to AL was slightly further out). Correspondingly, the judged size of the moon in mask VF was the greatest. This is illustrated in Figure 5. It is as if the presence of nearer ground texture "pulled" the responses to slightly closer accommodations. It should be noted that in Figure 5 the size judgments for all six subjects in this study are included. Size judgment data in Table 1 are limited to those four subjects for whom accommodation was measured.

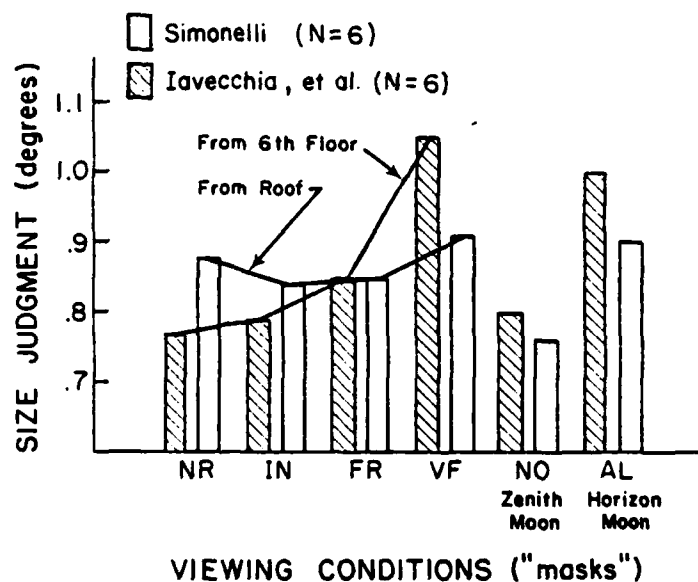


Figure 5. Mean size judgments of horizon moon in various daytime configurations found in the present study and the Iavecchia study.

The "no-terrain" condition, where the entire below-the-horizon portion was masked out, elicited one of the closest responses in both studies. That is, the "distant," isolated moon itself -- similar to the zenith moon -- was not a strong stimulus to distant accommodation

and, correspondingly, the size judgments to this stimulus were smaller.

In summary, it has been found that observation of various scenery, all well beyond the optometrist's "optical infinity" (6 m), elicited a variety of accommodation responses with concomitant changes in size judgments of a full horizon "moon"; the nearer the accommodation, the smaller the judgment. It was also observed that the response to a stimulus configuration similar to the zenith moon elicited a near response. This invokes an alternative interpretation of the moon illusion, one involving differential accommodation. The apparent size of the horizon moon is a function of exactly what terrain intervenes between the viewer and the horizon.

The implications of these findings extend beyond the moon illusion. Reduced stimulus situations, such as search for other aircraft at night or approach to a well lit airport environment over an unlit expanse of water, may result in size/distance judgment errors and be a factor in the well-known tendency for pilots to fly dangerously low at night.

DEFINITION

Diopter = inverse of the focal length of a lens in meters; 0 D = "optical infinity" (parallel light rays). 1 D = 1 m, that is, a 1 D lens will bring parallel rays to a focus at 1 m from the lens center. The eye at 1 D is focused for a distance of 1 m. Further, 2 D = 1/2 m, 1/2 D = 2 m, etc. The higher the dioptric value of the eye, the nearer it is focused.

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