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Overflow, First-Sight, and Vanishing Point Distances in Visual Imagery

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The relationship between the size of a familiar object and the distances at which it is imaged is examined in three experiments. The distance at which an imaged object overflows the visual field is linearly related to object size, a result consistent with the size–distance invariance hypothesis (Kosslyn, 1980). The distance at which an object is initially imaged, first-sight distance, is related to the object size by a power function with an exponent less than 1. In addition, time required to scan from the first-sight to the overflow distance increases as a function of the difference between the two distance estimates. The distance at which an imaged object becomes too small to be identified, vanishing point distance, is related to object size by a power function with an exponent less than 1. This result does not support predictions made from the size–distance invariance hypothesis or Kosslyn's model of visual imagery. Implications for a theory of visual imagery and memory are discussed.

In an attempt to measure the fraction of the visual field implicitly used by subjects engaged in visual imagery, Kosslyn (1978, 1980) found a linear relationship between the metric size of a familiar object and the subjective distance at which an image of that object overflowed the boundaries of the mind's eye. Such a result is compatible with the size–distance invariance hypothesis (SDIH) traditionally invoked in studies of spatial perception (Baird, 1970; Epstein, Park, & Casey, 1961; Sedgwick, 1986): For a fixed visual angle (ϕ), the ratio of perceived size (S) to perceived distance (D) is constant.

$$\tan \phi = S/D \text{ or } D = (1/\tan \phi)\, S \qquad (1)$$

That is, physically large objects are seen as more distant than smaller ones subtending the same visual angle.

In the typical imagery experiment a subject forms an image of a familiar object and "mentally" approaches it until the outer edges of the object begin to exceed the boundaries of the visual field. This "overflow" point is taken to indicate the distance at which the subject can no longer image the entire object at once, thus demarking, by inference, the limits of an internal buffer (Kosslyn, 1980). The estimated distance to the object at this point is then related to its given metric size in order to assess the validity of Equation 1 and thereby derive the maximum visual angle (ϕ) of the internal buffer. This maximal imaged angle is, however, not constant. The particular object that is imaged influences the limits of the visual field, as evidenced by the wide range of values (13° to 50°) Kosslyn obtained for different classes of objects. Such findings imply that the SDIH is satisfied but that different linear functions (slopes) hold for different categories of objects.

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Kosslyn's approach assumes that information (analogue, propositional, or otherwise) is available in memory for creating an internal pattern of an object. It is not clear whether the stored information necessary to create images needs to be explicitly represented at any particular metric scale. The scaling of size–distance combinations that satisfy Equation 1 may result from subsequent manipulation of a created image, rather than from information stored in memory. A number of studies suggest that the memory of a specific perceptual episode may already contain metric information (see also Tulving, 1972, 1983). Undergraduates are extremely accurate in estimating from memory a variety of stimulus attributes in their familiar environment, including the distances between campus buildings (Baird, Merrill, & Tannenbaum, 1979; Sherman, Croxton, & Giovanatto, 1979), the quality of visual and auditory aesthetics at outdoor locations (Merrill & Baird, 1980), as well as the number and nature of social activities occurring indoors (Baird, Noma, Nagy, & Quinn, 1976). In addition, studies of mental psychophysics in which subjects compare attributes of objects on different dimensions suggest that information specific to episodic exemplars can be used in mental comparisons (Hubbard, 1988; Kerst & Howard, 1978; Moyer, Bradley, Sorenson, Whiting, & Mansfield, 1978).

Models of imagery such as Kosslyn's (1980) claim that a surface image can be inspected and transformed by a number of processes such as scanning or "mentally walking." Distance estimates are typically collected from subjects after the image has been transformed, not before. In a series of recent experiments, with no specific visual angle implied (e.g., extent of imagined overflow), we found a positive relationship between recalled or imaged distances and the size of familiar objects prior to any transformation (Hubbard, Kall, & Baird, in press). We refer to such judgments as reflecting the "first sight" of the imaged or remembered object. The resulting functions were nonlinear, and therefore not in agreement with Equation 1, but could be fit by a more general power function with an exponent between 0.5 and 0.7, depending on the nature of the objects; that is,

$$D = \lambda S^{\gamma} \tag{2a}$$

$$\log D = \gamma \log S + \log \lambda. \tag{2b}$$

Kosslyn (1980) briefly reported studies on the "spontaneous distance" at which animals are initially imaged. He described spontaneous distance as a linear function of object size, despite the fact that "although people tended to image smaller objects as if they were closer, they did not always seem to maintain a constant subjective size in their images; even excluding larger animals did not allow us to fit a function indicating that a constant angle was subtended when images were evoked from long-term memory" (p. 218).

What subjects are doing in such imagery tasks may be like the following: When asked to recall or image a familiar object, subjects form an image of the object. The image, once formed, contains metric information such as size and distance. Subjects are able to report on these properties prior to any manipulation of the image. Although the metric information present in the memory of a perceptual event may not satisfy geometric models such as represented by Equation 1, it may nonetheless be lawfully related to other metric information also present in the memory. If this is so, specification of one variable (such as size) should lead to constraints on other variables (such as distance) even in untransformed images. If subjects are then given instructions to mentally approach the object, they manipulate the image in such a way as to bring about the desired relationship between themselves and the objects portrayed. This manipulation causes further changes in the portrayed metric values. For example, an image transformation in which the subject approaches the imaged object decreases the portrayed distance and increases the proximal size of the object.

Kosslyn obtained estimates of spontaneous distance and overflow distance from separate groups of subjects (and hence from separate images). In principle, however, it should be possible to obtain multiple distance estimates based on the same image, for example, before and after transformation to overflow. Accordingly, in Experiments 1 and 2 we collected estimates of imaged distance for the initial imaged distance and the overflow distance. We predicted that the initial distance estimates would conform to Equation 2 but that the overflow distances would conform to Equation 1. In Experiment 3, we further examined the validity of Equation 1 for a different visual angle that associated with an imaged vanishing point. From the standpoint of geometry, the latter condition is a trivial extension of the size–distance invariance hypothesis, but from the perspective of psychological modeling, the two conditions may be quite different.

Experiment 1

In Experiment 1 subjects gave two distance estimates based on the same image. The first estimate was of the distance portrayed in an initial, untransformed image of an object, and the second estimate was of the distance portrayed in a transformed image of that object where the object had reached the point of apparent overflow. We will compare the functional relationships between imaged distance and familiar size for both of these conditions. The questions of interest concern the similarity of these two types of judgments and the applicability of Equations 1 and 2 to imaged distance.

Method

Subjects. Twelve Dartmouth undergraduates participated for extra credit in an introductory psychology course. All subjects were naive to the purposes of the experiment. Data from 3 other subjects were discarded because they had difficulty performing the task.

Materials. We combined the names of 18 familiar objects from our previous study (Hubbard et al., in press) with the names of 14 animals used by Kosslyn (1978) for a total of 32 stimuli (see Table 1). These stimuli were listed in random order on two sheets of paper. The leftmost column of each page gave the name of each object, and the adjacent column gave the size of that object on its longest dimension (height, width, or length). To the right of the size column were two columns of blanks in which subjects wrote their distance estimates.

Procedure. Participants were run in subgroups of 3 or 4 but worked individually. They read the name and size of an object and then formed a mental picture of it. They were told to close their eyes

Table 1
Names and Sizes of Stimuli

Object	Size
From Hubbard, Kall, and Baird (in press)	
coin	1 in. wide
coffee mug	4 in. tall
dollar bill	6 in. long
toothbrush	6 in. long
chalk eraser	6 in. long
soda can	6 in. high
pencil	8 in. long
beer bottle	9 in. high
dinner plate	10 in. wide
football	12 in. long
license plate	12 in. long
house cat	12 in. high
rooster	18 in. high
stop sign	2 ft. wide
cow	4.5 ft. high
teacher	5 ft., 10 in. tall
policeman	6 ft. tall
refrigerator	6 ft. tall
From Kosslyn (1978)	
turtle	6 in. wide
beaver	3 ft. long
goat	3 ft. tall
boar	3.5 ft. long
collie	3.5 ft. long
kangaroo	5 ft. tall
donkey	5 ft. tall
moose	6 ft. long
seal	6 ft. long
horse	6 ft. high
alligator	9 ft. long
hippo	10 ft. long
elephant	12 ft. high
giraffe	14 ft. high

to aid in visualization. Their task was to estimate how far away (in feet and inches) a real object would be in order to look the same subjective size as the object in their mental picture when it was first formed. We refer to this as the *first-sight distance*. This value was then entered on the data sheet.

Subjects were next told to reform the image, mentally walk toward the object, and stop when they reached the point where they could not see all of the object at once; that is, without shifting the gaze of their mind's eye. They then estimated the distance to the object from that point and wrote the value on the data sheet. These instructions were adapted from Kosslyn (1978). Following Kosslyn, we refer to this second judgment as the *overflow distance*. Subjects repeated the procedure for all 32 items.

Results and Discussion

A median value was computed for each object for both the first-sight and overflow conditions. We chose medians because of the substantial intersubject variability.

First-sight distance. In Figure 1 the median first-sight estimates are plotted as a function of object size. The axes are logarithmic in order to assess the validity of the power function (Equation 2) as a descriptive model. Least squares regression yields a y-intercept of 0.62 and a slope (exponent) of 0.72, (r^2 = .98). The exponent is larger than those obtained previously and the fit is better (cf. Hubbard et al., in press). The stimuli in the various studies were different, and this could account for the slight discrepancy in exponents.

Overflow distance. If the overflow estimates are fit by Equation 2, that is, plotted in logarithmic coordinates, a y-intercept of 0.02 and an exponent of 0.92 are obtained. An exponent of 1 indicates the validity of the linear function described by Equation 1; the value of 0.92 is close to 1, indicating a function that is approximately linear. Figure 2 shows the relationship between overflow distance and object size in linear coordinates. Least squares regression (Figure 2) yields a y-intercept of −0.16 and a slope of 1.02 (r^2 = .96).

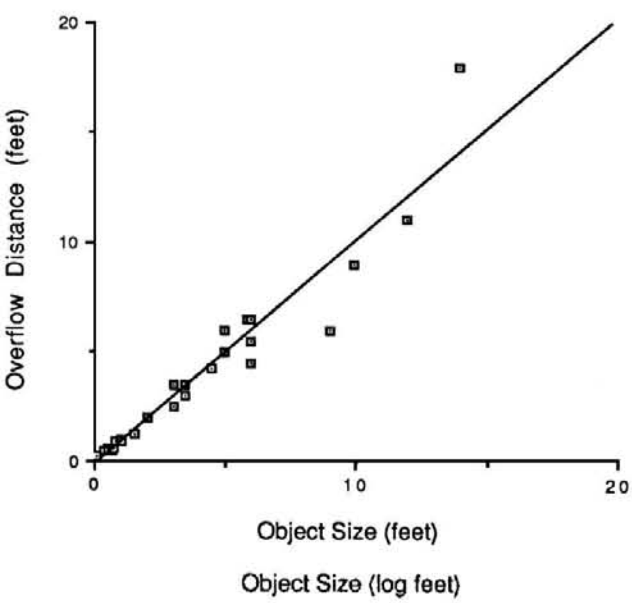

Figure 1. Median first-sight distance as a function of object size in Experiment 1 (logarithmic coordinates).

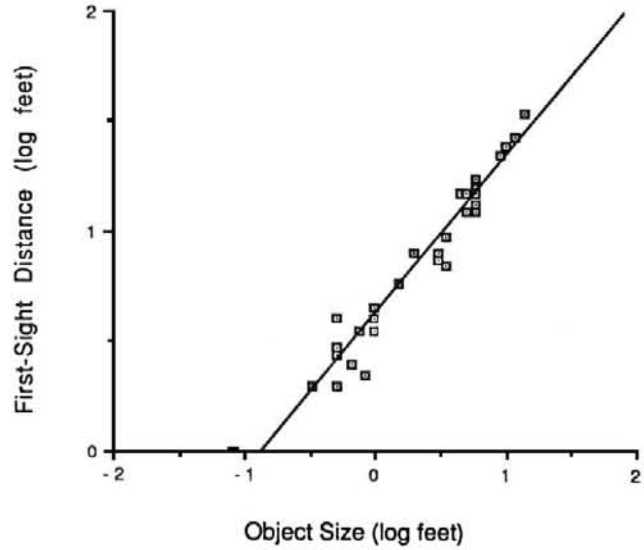

Figure 2. Median overflow distance as a function of object size in Experiment 1 (linear coordinates).

The distance at which an object overflows the imaged visual field is linearly related to object size in accord with the SDIH; larger objects overflow at farther distances than smaller ones. The linearity of the function replicates Kosslyn's original finding of a constant maximum visual angle in imagery. The differences between the first-sight and overflow functions shows that procedures designed to measure the size of the "mind's eye" in imagery require more of the subject than simple recall of a first-sight perceptual scene.

Visual angle at overflow. Because the y-intercept was essentially 0, we calculated the visual angle at overflow based on the inverse of the slope of the function in Figure 2 (see Equation 1). In the natural environment, size and distance can be viewed as the two legs of a right triangle, with the size of an object as the far leg and the hypotenuse of the triangle as the boundary of the visual field. This makes the ratio of size to distance equal to the tangent of the angle. This ratio is the inverse of the slope of the line shown in Figure 2 (1/1.02 = .98). In order to determine the angle at overflow, the arctangent function is computed. According to this computation the visual angle of the mind's eye for this particular set of stimuli is 44.4°. This value is on the high side of the range of visual angles reported by Kosslyn (1978).

First-sight and overflow. In logarithmic coordinates there is a strong linear relationship between first-sight and overflow distance (r^2 = .97). Least-squares regression results in an intercept of −.73 and a slope of 1.24. The fact that the slope is greater than 1 indicates that distances between the first-sight and overflow points are progressively larger with larger object sizes. Larger objects are imaged at farther distances, and they also have greater differences between first-sight and overflow points (at least over the size range tested here). It is important to note that the relationship between the first-sight and overflow distances is logarithmic; that is, overflow distance is not simply proportional to first-sight distance. This suggests that the process underlying transformation to overflow distance is different from the process that yields first-sight distance.

Experiment 2

The difference in distances between first-sight and overflow in Experiment 1 was less for small objects than for large ones. To check the reliability of this finding and look more closely at the relationship between the first-sight and overflow points, in Experiment 2 we asked whether response time to scan between first-sight and overflow distances was a positive monotonic function. Such a prediction follows from a model that invokes active transformation of an image from first sight to overflow. Although in many earlier studies "scanning" of an image was limited to shifting attention across the surface of an image, we broadened the notion of scanning to include shifting attention in depth.

Method

Subjects. Nineteen Dartmouth undergraduates participated for extra credit in an introductory psychology course. All were naive to the purposes of the experiment. Data from 3 other subjects were not used because they had difficulty performing the task, and the data from an additional 2 subjects were discarded because of equipment malfunction.

Materials. The stimulus materials consisted of the same object names and sizes used in Experiment 1. They were individually displayed on an Apple Macintosh computer.

Procedure. Subjects were run individually. There were 6 practice trials and 32 experimental trials. Subjects were allowed to repeat the practice trials if they requested or if they appeared confused about the task, which was admittedly difficult.

The name and size of each object were displayed on the computer screen. Each subject received the trials in a different random order. Subjects positioned their hands over the keyboard so that the "s" and "l" keys could be pressed without having to search for them. They read the name and size of the object, then closed their eyes to aid visualization. When an image of the object was clearly formed, subjects gave a numerical estimate of its subjective distance. We refer to this estimate as the first-sight distance.

Subjects then reformed their images of the object at the same subjective size and distance. Once they had reformed the image, they pushed the "s" key (left hand) and began to mentally approach the object. Depression of the "s" key activated a timer within the Macintosh. Subjects were told to stop their approach just as they reached the point where they could not see the whole object at once. When this point was reached, they pressed the "l" key (right hand) and gave a distance estimate. This second press turned off the timer and caused a new stimulus name and size to be printed on the screen. We refer to this estimate as the overflow distance. The procedure was repeated for all stimulus objects.

Results and Discussion

A median distance was computed for each object for both the first-sight and overflow conditions. As in Experiment 1, we chose medians because of the substantial intersubject variability.

First-sight distance. In Figure 3, median values for first-sight estimates are plotted as a function of object size. The axes are logarithmic in order to assess the validity of the power function (Equation 2). Least squares regression yields a y-intercept of .79 and a slope (exponent) of 0.55 ($r^2 = .93$). The obtained first-sight function resembles that of the imagery conditions in Hubbard et al. but is less than the exponent for the first-sight condition of Experiment 1. The difference in slopes between Experiments 1 and 2 may have been due to the additional tasks in the latter experiment. However, the higher percentage of variance accounted for, as well as the relative similarity of size-distance functions in both experiments, suggests that a power function offers a reliable description of the data. When instructed to image an object so that it could be seen all at once, subjects tended to image the same objects in the two experiments at roughly the same distances. The distances, as expected, were generally larger with increasing object size.

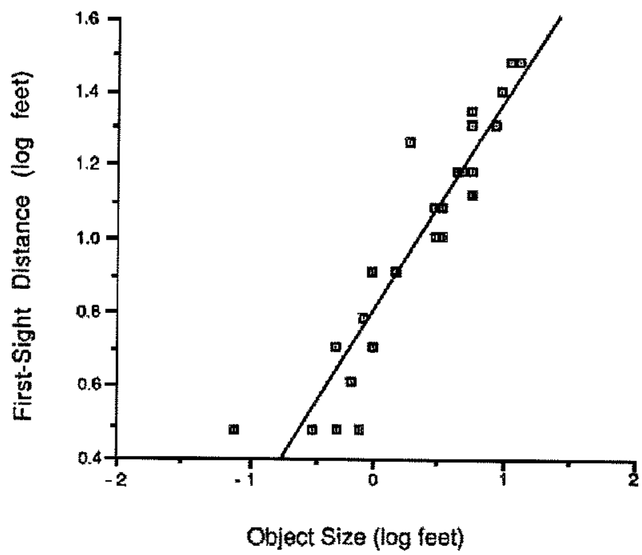

Figure 3. Median first-sight distance as a function of object size in Experiment 2 (logarithmic coordinates).

Overflow distance. As in Experiment 1, the exponent of logarithmically transformed data is close to 1 (0.90), indicating that the function is approximately linear. Figure 4 shows the relationship between the overflow distance and object size on linear axes. Least squares regression analysis yields a y-intercept of −0.01 and a slope of 0.85 ($r^2 = .96$). Although the linear relationship between imaged overflow distance and size was replicated, this slope is somewhat lower than that found in Experiment 1. As with first-sight distance, the lower slope for overflow distance obtained in this experiment may have resulted from the additional task demands on the subject.

Visual angle at overflow. Because the y-intercept was essentially 0, we calculated the visual angle at overflow based on the inverse of the slope of the function in Figure 4; that is, $1/0.85 = 1.18$. In order to determine the angle at overflow, we found the arctangent function of the inverse of the slope; it was 49.6°. This angle is comparable to that obtained in Experiment 1 (44.4°) and is at the upper boundary of the range reported by Kosslyn. In neither experiment did we stringently define overflow for subjects; they were told to

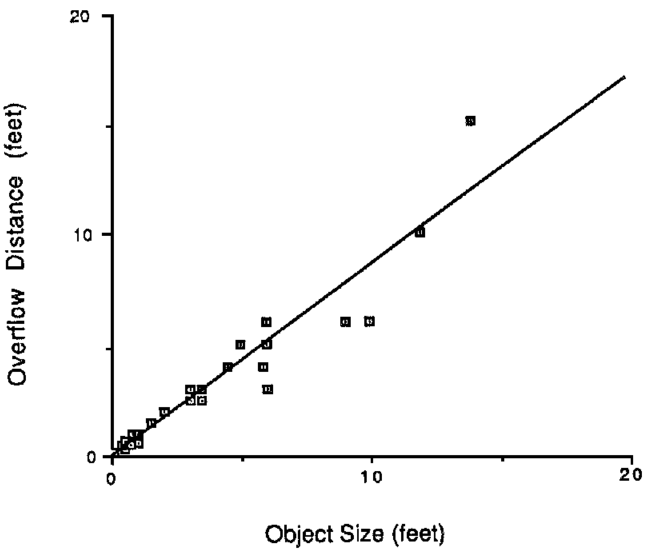

Figure 4. Median overflow distance as a function of object size in Experiment 2 (linear coordinates).

report the overflow distance as "that distance when you can't see the whole object at once." Some subjects noted a gradual "fade-out" of the edges of their images, suggesting a reduced acuity in the mind's eye (see Finke & Kosslyn, 1980; Finke & Kurtzman, 1981). As suggested by Kosslyn, this fade-out may in part account for the variety of visual angles obtained.

First-sight and overflow. On logarithmic axes, there is a strong linear relationship between first-sight and overflow distance, $r^2 = .93$. Least squares regression of overflow distance on first-sight distance on logarithmic axes reveals an intercept of 1.14 and a slope of 1.46. The fact that the slope is greater than 1 indicates that, as in Experiment 1, the ratio of overflow to first-sight distance is progressively increasing.

Scan distance and response time. Scan distance was calculated by subtracting the overflow distances from the first-sight distances for each subject. A median scan distance and median response time for each object were calculated, and those values are plotted in Figure 5. Regression analysis of response time against scan distance on logarithmic axes yields a y-intercept of 3.68 and a slope of 0.12 ($r^2 = .38$), indicating that response time increases very slowly with respect to increases in scan distance.

We expected the relationship between scan distance and response time to be positively monotonic. Previous studies have reported a linear relationship between scan times for both two-dimensional (Jolicoeur & Kosslyn, 1985; Kosslyn, Ball, & Reiser, 1978) and three-dimensional displays (Pinker, 1980; Pinker & Kosslyn, 1978), but these studies have generally involved changes across the surface of an image, and hence involved axes other than the depth axis.

Studies of mental size scaling (Bundesen & Larsen, 1975; Larsen, 1985; Sekuler & Nash, 1972) have generally found that reaction time to classify whether two objects have the same shape is a linear function of the size ratio between the stimuli. One study of mental size scaling, however, does suggest a possible reason why the function we found deviates from linearity. Larsen and Bundesen (1978) reported a linear relationship between size ratio and response time when a single image was transformed, but they found a logarithmic relationship when the entire visual field was rescaled. Because images of familiar objects frequently contain a background or context (Hubbard et al., in press), subjects transforming an image from first-sight to overflow would have to transform not an isolated single object, but an entire scene. A long mental walk would produce substantial changes in the imaged background as well as in the imaged figure.

The slow increase of response time with scan distance may also be due to the very large distances scanned by our subjects. Indeed, some of the scanned distances were so large that some subjects expressed a certain impatience at being constrained to walking speed. Other subjects spoke of a rapid "zooming in" on the originally distant objects, despite attempts to approach more slowly. Consistent with this, Finke and Shepard (1986) noted that when people image themselves performing a lengthy activity (such as a long walk) they do not image the complete uninterrupted sequence of movements, but "skip ahead" to points along the way. Most studies investigating imaged depth have used a small fraction of the third dimension, such as depth in a box. Our imagery situation was not limited in this way, but was free to extend out to the imaged vanishing point. It may be the case that scan time as a function of distance appears linear over a narrow range of depth, whereas scanning over an extensive depth interval is best described by a power function with an exponent much less than 1.

Experiment 3

In Experiments 1 and 2 we distinguished between the distance at which an object is initially imaged and that distance at which the same object becomes too large to be imaged all at once. These two distances are lawfully related to the size

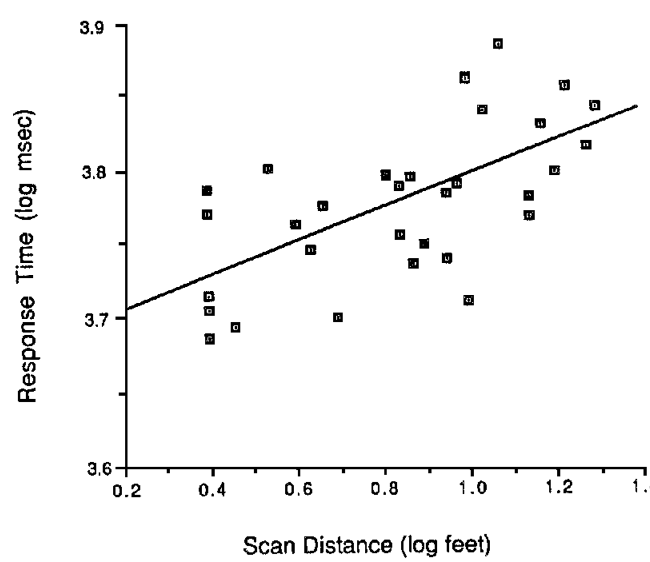

Figure 5. Median response time as a function of median scan distance in Experiment 2 (logarithmic coordinates).

of the object. The question naturally arises as to whether other visual angles could be chosen for which imaged distances systematically relate to object size. For example, is there a vanishing point distance beyond which an imaged object cannot be seen? The overflow distance is measured by having subjects mentally walk toward the object in their image, perhaps a vanishing point distance can be measured by having subjects mentally back away from that object. If this is so, is the point at which an imaged object becomes vanishingly small related linearly to object size, as predicted by the SDIH? Such a result would lend credence to a model of imagery in which a lower limit exists on the resolution of an image in order for it to remain recognizable (see Kosslyn, 1975). This limit should be a constant for different objects. Alternatively, the imaged vanishing point might be represented by the same nonlinear size–distance function found for first-sight distance. This outcome would require the postulation of some process either at the level of image construction or in the judgment strategy itself in order to explain the deviation from linearity.

Also of interest is the contribution of object type. Previously (Hubbard et al., in press) we obtained distance estimates of both imaged familiar objects and unfamiliar rods. This type of distance is analogous to the first-sight distance of Experiments 1 and 2. By having subjects image unfamiliar rods, we reduced the element of experience with a specific familiar object, thus revealing a purer contribution of object size. We found that measurements of imaged unfamiliar rods and familiar objects were both described by a power function with an exponent of approximately 0.6; therefore, it is of interest to examine imaged distances of unfamiliar rods for both overflow and vanishing points. If the imaged distances for familiar objects differ from the distances of rods matched for size, then familiarity may influence distance. Although factors other than familiarity—for example, figure complexity—may also distinguish the rods from the familiar objects, these factors are not considered here. If the imaged distances of familiar objects and unfamiliar rods do not differ from each other, then both familiar object and rod distances may be constrained by factors other than familiarity or stimulus complexity.

Method

Subjects. Twenty-four Dartmouth undergraduates participated for extra credit in an introductory psychology course. Subjects were all naive to the purposes of the experiment.

Materials. We combined the names of the 32 familiar objects from Experiments 1 and 2 with 19 rods of the same stated size for a total of 51 stimuli. There were fewer rods than familiar objects because several of the familiar objects were of the same size. The name of each stimulus and its size on the longest axis were listed on individual 4 × 6 in. unlined file cards.

Procedure. Participants were run in subgroups of 4 or 5 but worked individually. Each subject received the stimulus cards in a different random order. Subjects read the name and size of a stimulus (either a familiar object or a rod) and then formed a mental picture of that stimulus. For each stimulus, half of the subjects gave the overflow estimate first and half gave the vanishing point estimate first. In the overflow condition, subjects were instructed to form an image of the object and then mentally walk toward it. When they reached the point where the stimulus had become too large to be seen all at once, they were to estimate how far away (in feet and inches) a real stimulus would have to be in order to look the same subjective size. In the vanishing point condition, subjects formed an image of the stimulus and mentally backed away from the object. When they reached the point where the stimulus had diminished in size so much that they could barely identify it, they were to estimate how far away (in feet and inches) a real stimulus would have to be in order to look the same subjective size. Subjects wrote both of these estimates on the appropriate stimulus card.

Results and Discussion

We computed median distances for each object for both the overflow and vanishing point conditions.

Overflow distance. The median overflow estimates for familiar objects are plotted in Figure 6. Least-squares regression yields a y-intercept of −0.07 and a slope of 0.67 (r^2 = .97). As in Experiments 1 and 2, the relationship between object size and overflow distance is linear (exponent in Equation 2 = 0.98), but the slope is markedly less than that obtained previously. The reason for this lower slope is unclear, but it may relate to the increased range of distances in the current experiment. The median overflow estimates for unfamiliar rods are plotted in Figure 7. Least-squares regression yields a y-intercept of 0 and a slope of 0.63 (r^2 = .97). Once again, the relationship between object size and overflow distance is linear (exponent in Equation 2 = 0.99). The slope for unfamiliar rods is similar to that of familiar objects.

Vanishing point distance. The median vanishing points for familiar objects are plotted in logarithmic coordinates in Figure 8. Least-squares regression yields a y-intercept of 2.07 and a slope (exponent) of 0.70 (r^2 = .94). The relatively low exponent shows that the relationship between object size and imaged vanishing point is a power function. This result is

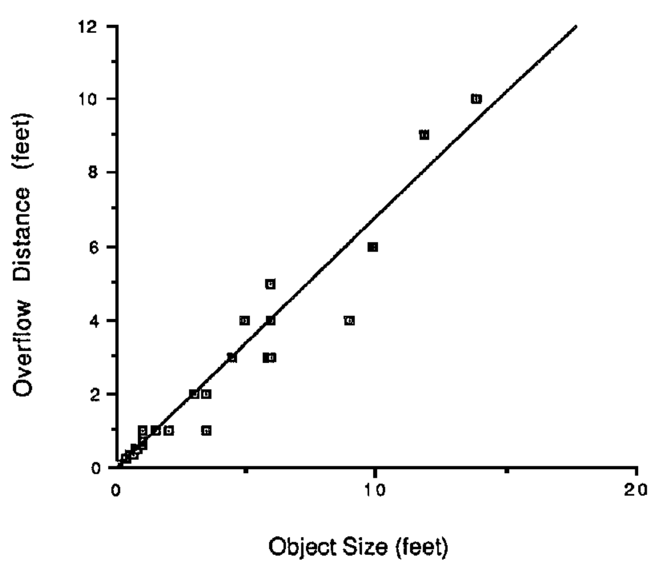

Figure 6. Median overflow distance as a function of object size in Experiment 3 (linear coordinates).

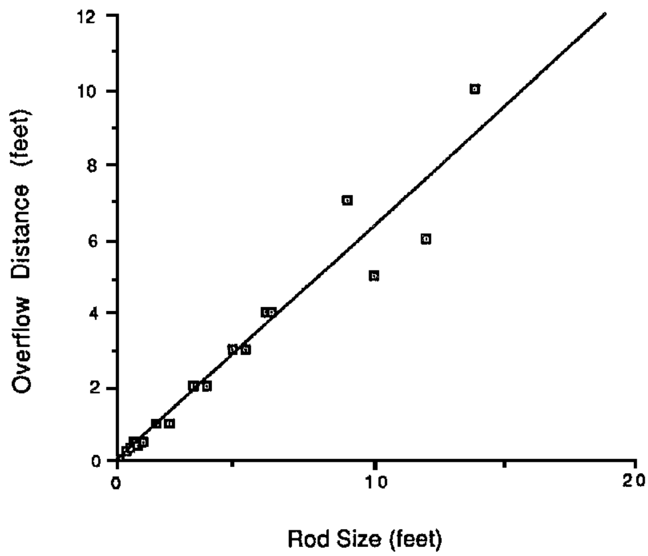

Figure 7. Medial overflow distance as a function of rod size in Experiment 3 (linear coordinates).

contrary to the linear relationship (exponent of 1) predicted by the SDIH, suggesting that factors other than visual acuity contribute to the imagined vanishing point. This result probably is not due to subjects' strategies when estimating large distances, because we previously obtained a linear relationship between estimated and physical distance of objects actually present at a wide range of distances in the natural environment (Hubbard et al., in press, Experiment 3). The median vanishing point estimates of unfamiliar rods are plotted in Figure 9 in logarithmic coordinates. Least-squares regression yields a y-intercept of 1.97 and a slope (exponent) of 0.67 (r^2 = .98). Like the familiar objects, vanishing point distance for rods is best related to object size by a power function with an exponent less than 1.

The similarity of the exponents for familiar objects and unfamiliar rods suggests that properties of the imagery system, rather than properties of the objects, determine the form of the vanishing point functions. The difference between the coefficients of determination (r^2 values) for both groups may have been due to familiar objects' being embellished with many surface details, whereas the unfamiliar rods were relatively featureless. The presence of surface details may have necessitated the familiar objects' being imaged closer so that the details could be seen more clearly.

Visual angle at overflow and vanishing point. We computed the arctangent function of the slope of the equations relating estimated overflow distance and object size; the maximum visual angles (overflow) for the familiar objects and the unfamiliar rods were 56.2° and 57.8°, respectively. These are somewhat larger than the visual angles obtained in Experiments 1 and 2 and are probably purer estimates of the maximum visual angle. The minimum visual angles (vanishing point) for familiar and unfamiliar objects in linear coordinates (though not as good a fit as for the logarithmic coordinates, r^2 = .89 for familiar objects and r^2 = .96 for rods) were 1.1° and 1.4°, respectively. The visual angle of the mind's eye thus appears to range from approximately a minimum of 1° to a maximum of 60°.

General Discussion

In agreement with Kosslyn's (1978) original work, we found a positive linear relationship between the stated size of an imaged object and the distance at which an image of that object overflows the boundaries of the mind's eye. Kosslyn (1980) took this result to mean that there exists an imaginal medium, or buffer, possessed of a fixed size, the extent of which is reflected by the maximum angle at which an object can be imaged. This maximum angle defines the largest size at which a subject can image an object and still view all of its parts. Imaged overflow distance apparently satisfies Equation 1.

By obtaining estimates of the imaged vanishing point, we expected that a minimum visual angle could be measured. If a constant minimum angle was found, then vanishing point, like overflow, would be subject to the SDIH and be described by Equation 1. We could then use the SDIH to describe both the upper and lower boundaries of the subjective sizes of imaged objects, and hence, of the mind's eye. Although we found a maximum angle, the nonlinearity of the relationship of the imaged distance estimates to object size in the vanishing point condition does not support the notion of a single minimum angle for imagery. What occurs, rather, is that the minimum angle is a function of the object size, with larger objects having relatively larger vanishing point visual angles than smaller objects. By collapsing across all object sizes, we were able to estimate a minimum angle of 1°, but this angle is only a rough approximation.

The failure of imaged vanishing point to obey the SDIH is puzzling. It probably is not due to an inability of subjects to estimate distance, because current literature suggests that the relationship between perceived distance and physical distance

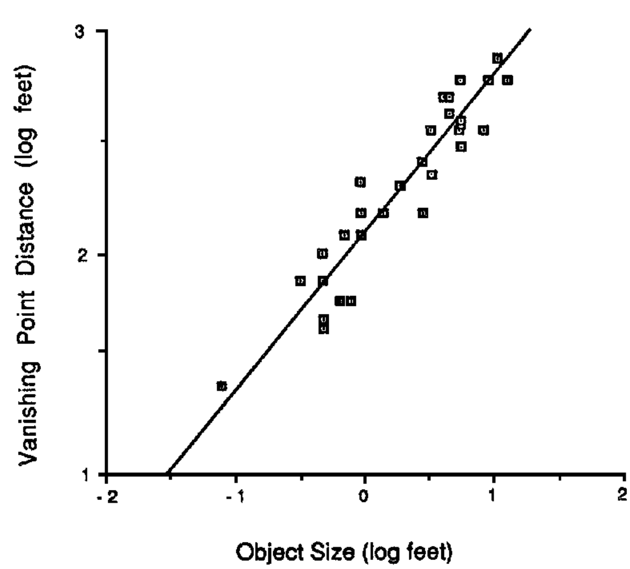

Figure 8. Median vanishing point distance as function of object size in Experiment 3 (logarithmic coordinates).

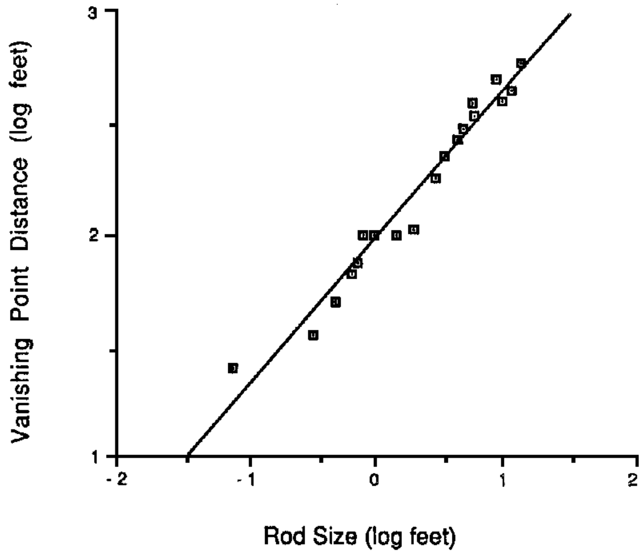

Figure 9. Median vanishing point distance as a function of rod size in Experiment 3 (logarithmic coordinates).

along the ground is either a linear function (Hubbard et al., in press; Wagner, 1985) or a power function with an exponent relatively close to 1 (for reviews, see DaSilva, 1985; Wiest & Bell, 1985; for exceptions see Sedgwick, 1986). Two possible hypotheses present themselves: Estimation of vanishing point distance is not constrained by graininess of the image, or the graininess of the image at any given point is not constant. Although in Kosslyn's model the grain concentration varies across the visual buffer, with the grain becoming coarser as the focus moves away from the center, the grain size at any particular point is assumed to be constant, or at least does not change size because of properties of the object that is portrayed. The first hypothesis implies that vanishing point distance is not read off the image, but is obtained in some other, nonimaginal way. The second hypothesis implies that the assumption of a constant grain size for a given area of the visual buffer is incorrect.

In Experiment 2, the relationship between scan distance and response time was nonlinear. We found a power function with a very low exponent, showing that even though greater distances require more time, in general the effect of distance is not overwhelming. Subjects "zoomed in" on the overflow point, thus compressing the amount of time required to hold and transform the larger distances in their images. Perhaps the rigors of constantly transforming across the relatively large imaged distances were fatiguing or boring, so subjects zoomed (or blink-transformed) instead of walked (or shift-transformed) in transforming their images. This compression of response time has implications for studies of image scanning. The speed of image scanning or the distance to subjective overflow may be cognitively penetrable dimensions of the task and not strictly limited by structural properties of the image (Pylyshyn, 1981, 1984; see also Goldston, Hinrichs, & Richman, 1985; Reed, Hock, & Lockhead, 1983). Alternatively, perhaps the attenuated slopes and response times were due to the more difficult nature of the latter experiments and resulted from a ceiling on the number of structural attributes of an image that a subject could correctly or fully manipulate at one time.

In sum, it is clear that there is specific metric information concerning object size and distance within both transformed and untransformed images. This information is either retrieved from specific episodes in memory or read off the image, when subjects are asked to give first-sight estimates. These estimates demonstrate a regular relationship between the stated size of an object and the distance at which it is initially imaged. This relation is a power function (Equation 2) with an exponent less than 1.

The image can then be transformed in at least two ways. One way involves mentally approaching the object in the image until it grows too large to be seen all at once. The overflow distance is a linear function of size as described by the size–distance invariance hypothesis (Equation 1). The second transformation is the reverse of the first one and involves mentally retreating from the imaged object until its proximal size is almost too small for the object to be identified. Unlike overflow distance, vanishing point distance is a power function of size (Equation 2) and fails to comply with the size–distance invariance hypothesis.

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Editor Named for APA's *Clinician's Research Digest*

The Publications and Communications Board has named George Stricker of Adelphi University's Gordon F. Derner Institute of Advanced Psychological Studies Editor of *Clinician's Research Digest* (*CRD*), which is being published by the American Psychological Association as of July 1988.

The six-page newsletter reports on research related to approaches to treatment modalities, including any systematic empirical study, as well as some coverage of child and gerontological issues. Although therapy is the main focus, key assessment and diagnostic questions as well as forensic issues are covered. *CRD* is an easy-to-read, fact-based, findings-oriented digest of research that summarizes for practitioners relevant material from the science base of practice. Complete citations are included so that clinicians interested in more information can request the full article from the author.

Although all published material will originate with the Editor, readers of *CRD* are invited to refer to Stricker any references or reprints of articles they find valuable.