these neurophysiological findings is the behavioral loss of acuity and pattern discrimination (*10*). Second, the deprivation also affects the nonspecific pathways of the brain (*5, 6*). It may be that changes in these pathways disrupt the animal's ability to use the visual stimulation for the control of its behavior (*5, 6*). In the present experiment, the loss of alpha blocking indicates that the deprivation has severed the functional connection between the primary visual pathways and those pathways of the nervous system, presumably nonspecific, that integrate the visual input with the attentional and arousal mechanisms of the brain.

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Mental Set Alters Visibility of Moving Targets

Abstract. *An observer's knowledge of a moving target's direction and velocity enhances detectability. In addition, knowledge of direction and velocity speeds an observer's reaction to the motion of a previously stationary target. Since rival, nonperceptual hypotheses can be ruled out, these effects represent a direct modulation of vision by mental set.*

Well-controlled experiments have established that a sound will be easier to hear if beforehand the listener can be certain what sound to expect and when to expect it (*1*). Everyday experience suggests similar influences of expectation on seeing, but attempts to demonstrate these effects rigorously have produced equivocal results (*2*). Now, using an objective psychophysical procedure we find that moving targets are easier to see if the observer knows what speed and direction to expect. Since alternative, nonperceptual explanations of this result can be ruled out, we are forced to conclude that mental set can affect even this basic perceptual function.

Our stimuli were random dot patterns presented on a cathode-ray tube (CRT) by a small computer (*3*). Viewing was binocular from a distance of 57 cm. When the dots were of sufficiently high luminance, an observer saw a sheet of about 500 scattered, bright dots moving at 4° per second along parallel paths within a circular aperture (9° diameter). In our first observations an objective psychophysical method, two-alternative forced-choice, was used (*4*). Every trial was divided into two intervals, each 600 msec long, separated by 1 second. During one of the intervals, dots moving steadily at 4° per second were presented; at all other times, including the other interval, the CRT screen was blank. The observer's task was to identify the interval that contained moving dots. A random number algorithm determined the interval, first or second, which would contain dots and which would be blank. A high-pitched tone, coextensive with each interval, defined the intervals for the observer.

In one condition, "stimulus-certainty," the dots' motion was always upward, and the observer could be certain about the direction to look for. In a second condition, "stimulus-uncertainty," the dots' direction of motion was unpredictable from one trial to the next. On half of the trials, the dots moved upward and on half they moved rightward; the two types of trials were mixed randomly. As before, the observer had only to identify the interval that contained the moving dots; no judgment about their direction was required. Fifty-trial blocks of "stimulus-certainty" and "stimulus-uncertainty" were run in alternation, with the subject being informed before each block of the condition to follow. This alternation ensured that any systematic long-term effects (such as fatigue) would affect certainty and uncertainty trials to the same degree. To optimize the observer's performance (*5*), feedback was provided after each correct response, in the form of an auditory signal.

Before collecting actual data from any observer, we found the luminance of dots which would produce about 75 percent correct performance under "stimulus-certainty." That luminance then was used for all subsequent trials. Complete data (300 trials per condition) were collected with two observers. Under "stimulus-certainty," the observations were 77 and 74 percent correct, but under "stimulus-uncertainty," with the same luminance, the observations were only 56 and 53 percent correct—nearly chance (50 percent) performance (*6*). Two supplementary observers, tested with fewer trials, gave similar results: 84 and 75 percent correct with "certainty" and 65 and 52 percent correct with "uncertainty." For all four observers, there was a wide separation between the 95 percent confidence intervals around the means for "stimulus-certainty" and "stimulus-uncertainty." Finally, there was no systematic difference between performance on the two types of uncertainty trials: those on which the dots moved upward and those on which the dots moved rightward. This can be seen in Fig. 1 where one observer's data are given for each of six 50-trial blocks.

The mathematical theory of the ideal detector states that the loss of visibility will be greatest when the two possible, alternative directions are detected by orthogonal (independent) mechanisms (*7*). If each motion mechanism were extremely narrowly tuned for direction, even directions which differed by far less than 90° would have to be processed by orthogonal mechanisms. But if motion mechanisms were very broadly tuned for direction, directions could differ by far more than 90° and still be detected by nonorthogonal mechanisms. As a result, we can use the effects of uncertainty to measure the directional selectivity of motion mechanisms. Suppose we measure the visibility of upward motion when, on any trial, the observer must watch for either upward or some alternative direction. The decline in visibility as the alternative direction departs from upward defines the sensitivity profile (direction tuning) of the upward mechanisms.

Since our two-interval forced-choice results were detection measures, they may be of only marginal relevance to everyday situations outside the laboratory. Consequently, we wanted to make measurements of uncertainty's effect with easily seen, suprathreshold stimuli; this required a different psychophysical procedure. To accomplish this we used reaction time as an index of the motion's visibility at suprathreshold levels; simi-

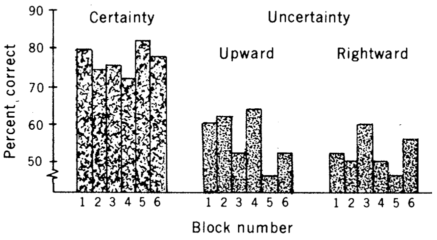

Fig. 1. Percent correct identification of the interval in which moving dots were presented. Each bar represents performance in a 50-trial block. Left and center groups of data are both for trials on which the dots moved upward. Data on the left are from blocks of trials on which dots moved only upward (certainty); center data are from blocks in which the dots moved rightward on half the trials (uncertainty). Data on the right are for those uncertainty trials on which dots moved rightward. The observer was K.B.

lar uses of response latency in suprathreshold audition experiments have been quite successful (*8*). Although the apparatus was the same as before, the dots were now of sufficiently high luminance (about 25 db above threshold) to make them easily visible. Each trial began with a blank CRT; the dots then appeared and remained motionless for a random interval (1 to 2 seconds). Without warning, the dots all began to move along parallel paths at 4° per second. The observer was instructed to push a telegraph key as soon as he saw the dots move. His response extinguished the dots, reinstating the blank CRT screen.

Reaction times (RT's) were measured for three observers in two different kinds of 50-trial blocks. In one type of block, observers could be certain about direction since the dots always moved upward; in the other type of block certainty was impossible—on half the trials some direction other than upward was presented. We wanted to see how the RT to upward motion would vary when, within a block, trials with upward motion were randomly interspersed among trials with some other direction. To ensure a good estimate of baseline, every third block was a certainty block (all upward motion). As before, the observer did not have to judge the direction; he merely had to hit the telegraph key whenever motion began. The results were clearcut. When the alternative direction was close to upward, RT to upward was affected very little; when it was quite different from upward, RT to upward was appreciably elevated. Figure 2 shows this variation in RT to upward motion (90°) as a function of the alternative direction of motion. All data are expressed as a ratio of (i) RT to upward with a particular alternative direction, to (ii) RT to upward by itself (*9*). A ratio of unity indicates that there was no effect of uncertainty; ratios greater than unity indicate that RT to upward was elevated by the potential presentation of the alternative direction. Although some additional assumptions (*10*) would be required to support any claim that the curve shown in Fig. 2 is the actual tuning curve for upward-sensitive visual mechanisms, it is likely to be at least a good approximation. Indeed, its similarity to tuning curves measured under somewhat different conditions is reassuring (*11*). By our measure, the mechanism that responds to upward motion shows a rapid decline in sensitivity as the stimulating direction departs from upward.

We have also begun to examine the effects of uncertainty about another aspect of a moving target, its speed. As before, we used the two-interval forced-choice procedure. With dots moving upward at 4° per second, we found the luminance that yielded 75 percent correct identification of the interval containing dots. But when the speed of the upward moving dots alternated unpredictably between 4° and 1° per second, this same luminance produced only 64, 68, and 68 percent correct, for three observers. Again, we should emphasize that the observer had to judge neither the speed nor the direction of the motion; he merely had to identify the interval containing dots. Moreover, related results on combined uncertainty about speed and direction have been gathered (*12*).

Although not directly related to stimulus-certainty, two reports made by our observers during forced-choice testing should be mentioned here. Three observers told us that they had to resort to extraordinary means in order to make correct responses. On some trials, they saw no dots, motion, or any other sign of the stimulus in either interval. Instead, during one of the intervals, they felt their eyes being "pulled" upward from the central position fixated at the start of the trial. To make correct responses on such trials, observers learned to recognize these pursuit eye movements triggered by unseen dots (*13*). This claim, if verified, would suggest that mechanisms which control pursuit eye movements are capable of responding to motion at luminances so low that the eliciting targets are actually invisible (*14*).

Our observers also noted that, on those trials where motion was visible, it often appeared to be restricted just to the peripheral portions of the 9° field (even though the dots were spread uniformly across the field). This observation is reminiscent of the suggestions, based on both psychophysics and physiology, that peripheral vision is somehow specialized for the detection of moving targets (*15*).

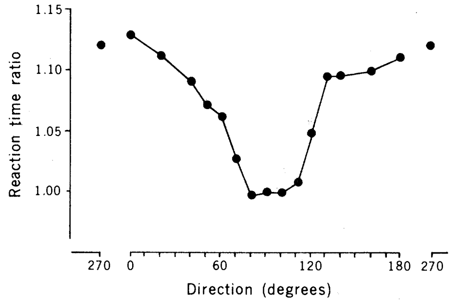

Fig. 2. Reaction time to upward (90°) moving dots as a function of the alternative direction which could have occurred. Data are ratio of (i) RT under direction uncertainty and (ii) RT under direction certainty (upward only). Means of three observers.

Most previous attempts to document the effect of mental set upon target visibility have been thwarted by rival hypotheses that attribute performance changes to various nonperceptual factors (*2*). These detailed hypotheses have concerned essentially four factors: (i) response bias—the set biases the observer toward making a particular response, regardless of what he actually sees; (ii) memory—the set alters the observer's memory of the percept; (iii) receptor orientation—the set changes that part of the display which the observer fixates; and (iv) order of report—the set alters the order in which the observer judges the several independent aspects of some complex stimulus. These factors do not offer plausible explanations of our certainty effects since (i) the relative proportions of "first interval" and "second interval" judgments in forced-choice testing did not change between "certainty" and "uncertainty" conditions; (ii) the reaction time procedure does not require the observer to store the percept in memory before responding; (iii) in neither of our procedures would the observer gain by changing his fixation as we went from certainty to uncertainty conditions; and (iv) observers had only to judge a single, constant aspect of the stimulus, for example, absence or presence.

We are left with the conclusion that mental set—foreknowledge about the character of the upcoming stimulus—affects visibility directly. This effect, though somewhat surprising on its face, is what mathematical descriptions of the ideal detector (*4*, *16*) lead one to expect.

Our results raise the possibility that performance on various visual tasks outside the laboratory is colored by uncertainty about target direction and speed. For example, uncertainty about direction and speed may well limit target acquisition by drivers, pedestrians, and pilots. In addition, uncertainty may also affect measurements made in vision clinics. Many ophthalmologists recognize that the apparent size and shape of visual fields can be altered by the patient's uncertainty about the direction in which the luminous test target will move in from the periphery of the visual perimeter. But intuition aside, it would be useful to have accurate data on the extent to which stimulus-uncertainty actually does limit visibility in everyday situations.

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9. The ratio expression of our data compensates for changes in baseline RT over our rather prolonged testing sessions. Analysis of variance showed that RT ratio varied in a statistically reliable way, with changes in the alternate direction, $P \leq .001$.
10. A key assumption would be that there was a linear relationship between RT and sensitivity of the mechanism under study. Although we doubt that linearity obtains strictly, the relatively small variation in RT with uncertainty gives us at least a small-signal approximation to linearity.
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12. R. Sekuler and K. Ball, paper presented at annual meeting of the Association for Research in Vision and Ophthalmology, Sarasota, Fla., April 1977.
13. Our results also tend to discredit the adage "Out of sight, out of mind."
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16. Our forced-choice results with direction uncertainty show a loss in performance that slightly exceeds the loss that an ideal detector would exhibit [J. Swets, Ed., *Signal Detection Recognition* (Wiley, New York, 1964), Appendix I, pp. 679–684].
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Striatal Efferent Fibers Play a Role in Maintaining Rotational Behavior in the Rat

Abstract. *Rats in which ascending dopamine-containing neurons have been unilaterally destroyed by injections of 6-hydroxydopamine are known to rotate after being injected with apomorphine or* L*-dopa. The rotation is markedly reduced by either (i) ipsilateral electrocoagulations of the caudate-putamen or internal capsule or (ii) ipsilateral coronal knife cuts immediately rostral to the substantia nigra. Neostriatal efferent fibers, in particular the strionigral projection, appear to be required for the expression of this dopamine-dependent behavior.*

Recent advances in the localization of neurons in the brain that contain catecholamine (*1*) have been associated with expanding interest in their behavioral functions. Much behavioral research has focused on the ascending neurons that contain dopamine (DA), and that originate in the mesencephalic cell groups A8, A9, and A10. These neurons give rise to axons that course through the medial forebrain bundle and internal capsule to terminate in the neostriatum (caudate-putamen), the nucleus accumbens septi, olfactory tubercle, cortex, and other limbic forebrain regions. When these neurons are destroyed bilaterally, rats display a syndrome of behavioral deficits characterized by failure to eat or drink, inattention to sensory stimuli, akinesia, and catalepsy (*2*). Certain clinical disorders of movement (for example, Parkinson's disease) also appear to be attributable to abnormalities of these DA-containing neurons. A possible dysfunction of these neurons in psychotic and manic states is also being investigated (*3*).

Despite the apparent behavioral significance of the ascending dopaminergic systems, the course and distribution of efferent fiber systems responsible for the expression of central dopaminergic activity has not been determined. We now report experiments intended to localize the efferent neurons of the basal ganglia that maintain the rotational behavior of rats with unilateral 6-hydroxydopamine (6-OH-DA) lesions of the ascending dopaminergic neurons, a behavior that depends upon the activation of forebrain DA receptors (*4, 5*). To study rotational behavior, rats were given an injection of the catecholamine neurotoxin 6-OH-DA to destroy most of the ascending dopaminergic neurons of one hemisphere. Several days later, when given systemic injections of compounds that result in direct DA-receptor stimulation (apomorphine or L-dopa), the rats turn vigorously away from the hemisphere of the DA neuron loss (*5*). This rotation appears to be due to the development of postsynaptic supersensitivity in the striatum ipsilateral to the 6-OH-DA injection such that the animal turns away from the hemisphere of the highest DA-receptor activity (*5, 6*). We then made electrocoagulations or knife cuts in the same hemisphere as the earlier 6-OH-DA injection. By analyzing the brain sites destroyed by those lesions effective in blocking rotation, we have been able to suggest the course of fibers leaving the strio-pallidal complex that maintain this behavior.

Male Sprague-Dawley rats ($N = 65$) weighing 150 to 200 g were given an injection of 6-OH-DA along the course of the ascending dopaminergic neurons of the left hemisphere (*7*). After 1 to 2 weeks, the rats were placed in a rotometer bowl (*4*) and given an intraperitoneal injection of apomorphine (0.25 mg per kilogram of body weight) or L-dopa (50 mg/kg). The number of turns to the left and right were recorded separately during the subsequent 60 minutes or until the rats stopped rotating. Testing was repeated 2 or 3 times per week for 1 to 3 weeks until each rat had exhibited stable rotation. Electrocoagulations (*8*) or knife cuts (*9*) were then made in the left hemisphere in an attempt to interrupt striatal efferent fibers that maintain the rotation. All rats were retested for rotation stimulated by apomorphine or L-dopa 2 to 4 times during the next 2 weeks. At the conclusion of the experiment each rat was killed, and its brain was removed for microscopic analysis of the lesion site. The brain was stained either with thionin stain or according to the fluorescence histochemical technique of Falck and Hillarp (*10*). We reconstructed the electrocoagulations or knife cuts using reproductions from the König and Klippel atlas (*11*), taking account of lesion-induced shrinkage and distortion of brain tissue.

Extensive destruction of the head of the caudate-putamen, completely sparing the globus pallidus and internal capsule, reduced apomorphine-induced rotation by 62 to 74 percent (*12*) in both