nephrine without affecting endogenous dopamine or norepinephrine concentrations (Table 1). These findings confirm in vivo our earlier findings in vitro that in nonstriatal synaptosomes *d*-amphetamine is a much more potent inhibitor of catecholamine accumulation than is *l*-amphetamine. We also confirm in vivo that *d*- and *l*-amphetamine inhibit to the same degree the accumulation of catecholamines into striatal synaptosomes.

d-Amphetamine was ten times as potent as *l*-amphetamine in enhancing locomotor activity (Table 2). With increasing doses of amphetamine there was an enhancement of locomotor activity up to a dose of 1.5 mg of *d*-amphetamine per kilogram or a dose of 12 mg of *l*-amphetamine per kilogram. After these doses of *d*- or *l*-amphetamine, equal peak locomotor activity was recorded. Further increases in dose resulted in decreased locomotor activity. This tenfold difference between the potency of the two isomers on locomotor activity closely parallels the tenfold difference of their potency in inhibiting catecholamine uptake by cerebral cortical synaptosomes (*6*).

There have been many theories to explain the stimulant action of the amphetamines in the brain, including synaptic release of norepinephrine (*11*), inhibition of its reuptake (*12*), inhibition of monoamine oxidase (*13*) and direct action on receptors (*14*). Our results suggest that inhibition of norepinephrine uptake may be a major mechanism of action. We also found that *d*-amphetamine was much more potent than the *l*-isomer in lowering endogenous norepinephrine concentrations. Because the doses of *l*-amphetamine required to decrease norepinephrine concentrations would be toxic, it is not possible to compare the potencies of *d*- and *l*-amphetamine in decreasing brain norepinephrine; therefore we cannot rule out the possibility that there also exists a close relation between the differential potency of *d*- and *l*-amphetamine in depleting norepinephrine and in stimulating locomotor activity, respectively. It is also unclear whether norepinephrine depletion is a result of inhibition of reuptake or is due to synaptic release of catecholamine by amphetamine.

d-Amphetamine was only about twice as potent as *l*-amphetamine in evoking the compulsive gnawing syndrome, and the differences between groups had only borderline statistical significance. The greater similarity of the two amphetamine isomers in eliciting gnawing than in stimulating locomotor activity, together with biochemical evidence in vivo and in vitro, of effects of the two isomers on uptake of catecholamine in the corpus striatum, suggests that gnawing behavior is related to an action of amphetamine on striatal dopamine neurons. Presumably, if gnawing were determined solely by dopamine tracts, *d*- and *l*-amphetamine should have been equal in their effects. The twofold difference in potency of these isomers indicates that norepinephrine neurons may participate to a limited extent in production of this behavior, possibly as a triggering mechanism.

Because there are a large number of norepinephrine-containing tracts in the brain, pharmacologic criteria, such as the different potencies of *d*- and *l*-amphetamine in producing locomotor stimulation, cannot readily delineate which isomer is involved in eliciting a given behavior. By contrast, there are only a few dopamine-containing tracts in the brainstem. Besides the nigrostriatal tract, which appears to be related to the gnawing behavior induced by amphetamine, other dopamine tracts arising in the brainstem have terminals in the olfactory tubercle and the nucleus accumbens (*5*). A dopaminergic tract originating in the arcuate nucleus of the hypothalamus and terminating in the median eminence has beeen implicated in regulating the synthesis and release of pituitary trophic hormones (*15*). Experiments with *d*- and *l*-amphetamine may help to elucidate the functions of these tracts.

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11 March 1970

Neural Symbolic Activity: A Psychophysical Measure

Abstract. *When a subject views a grating which is partially blocked from view by a cube, adaptation (decrease in contrast of the grating) occurs not only to the visible portions of the grating, but also to those portions blocked from view. This may indicate the existence of a neural mechanism which conveys the information "in back of."*

When a grating is viewed for a prolonged period, discrimination thresholds to the same and similar gratings are subsequently raised, or the apparent contrast of the same and similar gratings is depressed, whereas thresholds to and apparent contrast of gratings differing in orientation or size remain unchanged (*1*). This is called adaptation, and indicates that different popu-

lations of neurons respond differentially to features of a stimulus (*2*). My study shows that when a subject views a grating which is partially blocked from view by a cube, adaptation occurs not only to those portions of the grating which are visible, but also to those portions blocked from view. This adaptation differs in amplitude and temporal characteristics from adaptation to a grating alone, from adaptation to a cube alone, and from adaptation to a blank field at a mean spatial luminance the same as that of the other adaptation fields. Such adaptation indicates that there may be neural representation in the visual system of the concept "in back of."

The ability to separate a scene into its components is vital for any pattern recognition. Simulations of pattern recognition which can effect such separations proceed, roughly, in two steps: (i) features are abstracted from the visual array; (ii) relationships between these features are tested with reference to internal models which specify how things are supposed to look in space (*3*).

It appears, from the adaptation work cited (*2*), that step (i) in computer recognition of patterns has some general analogy to initial sensory activity in the human visual system. However, there have been no psychophysical tests so far of visual processes analogous to step (ii)—the further processing of features in terms of internal models.

What neural mechanisms could mediate this further processing? Electrophysiological studies (*4*) indicate that neural activity in the visual system continues throughout pattern recognition and does not stop with receipt of the primary physical stimulus. Thus, step (ii) processing may involve, in some way, the same units of the visual system involved in step (i) processing. If so, adaptation paradigms ought to be able to test step (ii) neural response.

For instance, consider the following simple scheme for separating a scene into its components. The concept that one object is obscuring another might be coded by the firing, in response to those places in the visual field where an object was blocked from view, of a subset of those neurons comprising the population which would ordinarily fire if the object were completely visible. Differences would be expected: if the response at those places where the object was obscured were identical to the response at those places where the object was in view, there would be no

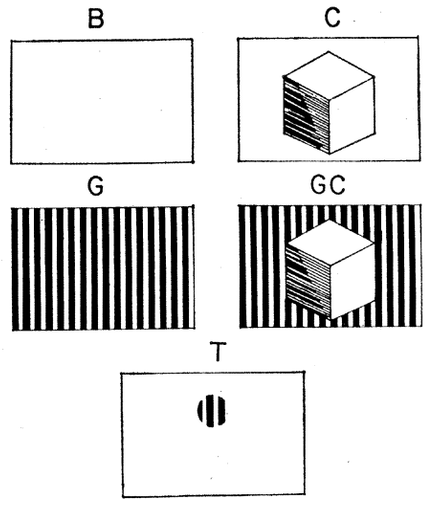

Fig. 1. Adaptation (rows 1 and 2) and test (row 3) stimuli. B, blank field; C, cube on blank background; G, grating; GC, cube in front of grating; T, test disk.

way of distinguishing between an internal construct and a physical event. But in both cases, if there were prolonged stimulation, adaptation would be expected. The following experiment tested this hypothesis.

The stimuli (Fig. 1), Kodalith slides, were presented tachistoscopically (Scientific Prototype, Model G) and transilluminated so that the lighted portions of the 2.2 cycle/deg of visual angle gratings (G) had a luminance of 34.6 mlam, the dark portions of the gratings were at a luminance lower than could be measured with a Zoomar photometer, and the portions without gratings (the blank field, B; cube, C; and cube in front of grating, GC) had a luminance of 17.3 mlam. Adaptation stimuli (with B, C, and G the controls, and GC the experimental condition) were each presented for 10 seconds; then after one of five interstimulus intervals (ISI = 0, 10, 30, 50, or 100 msec) a test disk (T), was presented for 16 msec, illuminated in its lighted portion at 3.5 mlam with a mean luminance of 1.7 mlam. The cubes measured 3.38° visual angle in maximum extent; their planes were indicated by three lines in the shape of a Y, and cross-hatchings with a spatial frequency of $\geqslant 10$ cycle/deg. Given the difference in orientation, size, and frequency of these cross-hatchings, with respect to the adaptation gratings, it was felt that main adaptation effects would not be significantly confounded. In addition, if there were secondary effects, they would occur equally for condition C and condition GC. The test grating, T, had the same spatial frequency and contrast as the adaptation grating, and was positioned in such a way that if it were presented simultaneously with GC or C, it would appear slightly off-center inside the top plane of the cube. At this position, the line drawn through the center of the disk to the nearest point of the grating in GC measures 25.8′ visual angle; this is the distance at which there would be maximum chance of eye movements resulting in stimulation of a small portion of the same retinal area by both the grating appearing in GC and the grating within the disk (T). Since the standard deviation of eye movements around a small fixation stimulus (*5*) is about 5′, the maximum probability of occurrence of an artifact due to eye movement is less than .00009. Thus, any adaptation effect found for condition GC could not be due to artifacts caused by eye movement.

Six subjects who had 20-20 vision, had not participated in psychophysical experiments before, and had not been told the purpose of the experiment made 12 estimates of the magnitude of the apparent contrast of the test grating at each ISI after each adaptation condition. The estimations

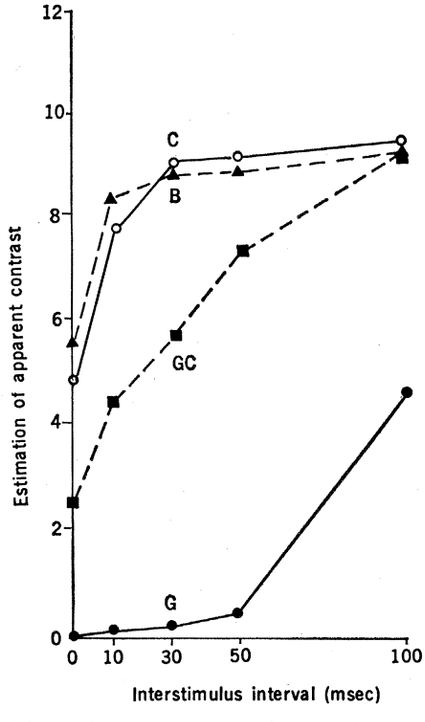

Fig. 2. Apparent contrast (geometric mean for six subjects) of test grating after adaptation to G (grating), GC (cube in front of grating), C (cube on a blank background), and B (blank field of the mean spatial luminance of the other adaptation fields).

were in terms of the proportion of decrease or increase in contrast of T with reference to a standard. The standard was the contrast of T after adaptation to condition B. Subjects had practice sessions until they could give consistent ratings for the standard. For each adaptation field, six consecutive trials were presented before a new adaptation field was presented. Each adaptation stimulus was presented for two sets of six consecutive trials for each ISI; the order of presentation of adaptation stimuli was random. Stimuli were viewed with one eye only. Since the estimate of error variance is computed from the subject interaction, not from the within-cells replications, the presentation of six consecutive trials does not artificially lower the error term in the statistical analysis. On the other hand, such a procedure permits a thorough testing of adaptation effects, since any decay from a previous adaptation field would enter into only the first one or two presentations, and any buildup of an adaptation effect would be included.

When the geometric mean contrasts of T for each ISI and each adaptation condition (Fig. 2) are analyzed one finds that the apparent contrast for GC is reduced and that the reduction is due neither to the effect of prolonged viewing of a cube alone (C), nor to adaptation to mean luminance (B). This depression also differs in both amplitude and recovery course from that occurring for G. There is a general depression of apparent contrast at the early ISI's, which is no doubt caused by a general masking-by-flashes effect (*6*).

The differences between conditions G, GC, and B and conditions G, GC, and C are highly significant. A three-way analysis of variance showed all measurable main and interaction effects significant at $P < .001$. For this design, the error term is the interaction including subjects; thus, the within-cells variance (which would be computed from each of six sets of 12 estimations of magnitude) does not enter into the calculation. A Duncan's multiple range test showed all main effects significantly different from each other at $P < .001$ except those between B and C.

The depression in apparent contrast for GC cannot be due to artifacts caused by eye movement. Nor can it be due to a difference in mean spatial luminance, since if this were so, there should be an identical depression for C. Thus, this depression in apparent contrast may indicate that certain subsets of neurons are active not in the presence of the physical stimulus, but to some internal representation of the meaning of that stimulus. If the object blocked from view (the grating) is in some sense completed by neural activity, that is, if neurons symbolizing grating fire as if to a grating, it would be likely that these neurons would fatigue or adapt upon prolonged viewing, just as neurons active when a grating is presented fatigue or adapt. A corresponding depression in apparent contrast would result.

The effect may be more general, however. Whenever a grating is present, neurons may respond in portions of a scene where the grating is blocked, whether or not that portion contains an object which is clearly perceived to be in front of that grating. Hence, in order to test that activity in response to nongrating portions of the stimuli used in this experiment actually symbolizes "in front of," it must be shown that, with scenes in which gratings are simply interrupted, such as a picture of a grating with a hole in its middle, there is no adaptation effect.

Although it is known from electrophysiological work (*5*) that there is activity in the visual cortex throughout the process of recognition and learning, there has previously been little in the way of psychophysical measures of neural activity beyond that of the initial registration of stimuli. The results of this experiment indicate that activity beyond this—higher-order-activity—can be measured. The possibilities for investigation of higher-order stages in pattern recognition implied by these findings are very broad.

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10 March 1970

Assessment of Multiattribute Preferences

Abstract. *Operational assumptions are made concerning the preferences of a decision maker. Functional forms of multiattribute utility functions that satisfy these assumptions are stated. These forms provide operational methods for assessing preferences over multiattribute consequences and have a wide range of practical application.*

A decision problem is one with more than one available course of action. A consequence will eventually result from any particular course of action the decision maker chooses to follow, and he must choose a "best" course of action from the alternatives. For example, the manager of a blood bank must choose an inventory ordering policy that best satisfies the objectives of his particular blood bank. For a certain policy, a consequence might be described by "five percent of the blood requested by doctors cannot be supplied from stock."

In such decisions, there is the ever-present problem that consequences can rarely be described completely in terms of one attribute, such as the "percent of unsupplied demand" in our example. In the general case, one might describe these consequences in terms of several attributes. For our example, the consequences of a particular inventory policy might be summarized adequately by the number of units of outdated blood, the percent of unsupplied demand, and the age of transfused blood. When more than one attribute is necessary to describe the consequences, they are called multidimensional consequences.

To complicate the problem further, uncertainty is often associated with the consequences. Again referring to our example, for a particular ordering policy one could probably not state beforehand the exact percent of unsupplied demand, the exact number of units outdating, and so forth. Therefore, with each specific course of action, various consequences would have various probabilities of occurring.

The general decision problem is summarized as follows. The decision maker has a number of alternative courses of action, each of which will eventually result in a multidimensional consequence. However, at the time this choice must be made,