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Stimulus Generalization in Humans Viewed from a Signal Detection Perspective[1]

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Eighty human subjects received 24 discrimination training trials, with appropriate feedback, for responding by saying "same" to one brightness of white light and "different" to another. They were then tested for generalization (without feedback) with seven equally-spaced brightnesses, including the original two, which were the second and sixth brightest in the 7-step series. The S+ ("same") and the S− ("different") were reversed between subgroups. For one group, S+ appeared three times as often as S− during discrimination training. For another group this ratio was reversed. It was predicted that the groups for which S+ was more frequent would respond (with "same") more to intermediate stimuli than would the groups for which S− was more frequent, whereas the latter groups would have a relatively enhanced tendency to respond to the test stimulus displaced from S+ to the side opposite S−. Both of these predictions were supported.

When stimulus generalization is studied in human subjects, verbal instructions to respond to a particular (training) stimulus value (and to no other) are often substituted for the operant or Pavlovian training given to nonverbal organisms (c.f. Brown, Bilodeau & Baron, 1951; Kalish, 1958). The gradients obtained, however, look much like those obtained in conditioning studies. It is typical that maximal responding occurs to the value of the training stimulus, with response strength systematically decreasing as a function of the distance between a given test stimulus and the training value. In the study of the generalization of a voluntary response in humans, however, two paradigms have been developed in which generalized responding tends to be maximal to a value other than that of the training stimulus. One of these involves a manipulation of the test stimuli. Thomas and Jones (1962) gave their subjects a single exposure to a 525 nm training stimulus with instructions to remember that stimulus so that they could identify it during a subsequent wavelength test. The location of the training stimulus in the test series was systematically varied, with the training stimulus being in the center of the range of test stimuli for one group, and displaced to different extents from the centre for four other groups. Only with the symmetrical group did a symmetrical generalization gradient (with a peak at the training stimulus) result. For the other groups, the peak was shifted toward the center of the test series.

Capehart, Tempone and Hébert (1969) proposed that this "central tendency effect" was explicable in terms of Helson's (1947, 1964) adaptation-level (AL) theory. According to this theory, subjects perceive and re-

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member stimuli not as absolute values but in relation to some internal representation of the "average" of previous experience with that dimension, called adaptation-level. Presumably, in the Thomas and Jones study the training stimulus was established as the initial AL. As AL changed during testing, moving toward the central value of the (asymmetrical) test series, subjects continued to respond to that stimulus which was closest to AL at any given time, resulting in the observed peak shift. The AL interpretation of the central tendency effect has been strongly supported in a series of studies reviewed by Thomas (1974). As far as we know, no other theoretical interpretation has been proposed to account for this phenomenon.

A second paradigm which produces generalization gradients with a displaced peak involves the use of successive discrimination training between two values on the test dimension, i.e. "intradimensional" discrimination training. In the first study of this sort with human subjects, Doll and Thomas (1967) trained one of their groups to respond to a monochromatic light of 530 nm but not to one of 550 nm. Subsequent generalization testing revealed a gradient which peaked at 520 nm, a value displaced from S+ so as to be farther removed from S−. A similar finding of a peak shift following intradimensional discrimination training has frequently been reported in the animal literature (c.f. Hanson, 1959; Thomas, 1962, etc.

In order to account for the occurrence of a peak shift after discrimination training, Thomas, Svinicki and Vogt (1973) extended the AL theory as follows. They argued that during training, the AL would be formed between the S+ and S− values, thus subjects would be responding to a value (i.e. S+) which was displaced from their AL. In generalization testing, the previous S+ is typically located at the center of the series of test values, and the AL should gravitate toward this value. Since the subjects had been trained to respond to a value which was displaced from their AL, they should continue to do so during testing, thus yielding a peak shift in their generalization gradient.

Although studies by Thomas *et al.*, (1973) and by Newlin, Rodgers, and Thomas (1979) indicated that changes in AL between training and testing can contribute to peak shift following discrimination, recent studies have also indicated that peak shifts can be obtained when AL remains constant. For example, Galizio and Baron (1979) trained subjects to respond to two positive stimuli (two tones varying in frequency) but not to respond to a third stimulus (S−) midway between the other two. A generalization test centered on the S− stimulus produced a gradient with a minimum at S− and increased responding in both directions as stimuli became more different from S−. Since the mean (and midpoint and median) of the training and test series were the same, no AL shift would be expected. Furthermore, an AL shift could not account for the *bidirectional* peak shift obtained.

A bidirectional peak shift was also found in a three-stimulus brightness discrimination study by White and Thomas (1979). Furthermore, Newlin *et al.*, (1979) have obtained evidence for two independent factors which contribute to peak shift following successive intradimensional discrimination training. The question that remains is how best to characterize the second (non-AL) factor. Galizio and Baron (1979) identify this factor by reference to Spence's (1937) gradient-interaction account of discrimination learning in animals. The peak shift is purportedly the consequence of the algebraic summation of a gradient of excitation centered about S+ and a gradient of inhibition centered about S−. This is, of course, the favoured interpretation of peak shift in animal studies (c.f. Hearst, 1968).

In studies of wavelength generalization in pigeons, which have excellent colour vision, responding occurs, albeit at a lower level, to test stimuli which are very discriminably different from the training value (e.g. red vs. green). In human studies, subjects are typically given explicit instructions not to respond (or to respond in a different fashion) to stimuli which are perceived as different from the training stimulus. Therefore in these human studies (assuming that the subjects follow instructions) responding to generalized stimuli must be attributed to a failure to perceive a difference. A perceptual explanation of the peak shift would seem more appropriate than a learning interpretation in these human studies.

One such interpretation is based upon the theory of signal detectability (TSD) (Green & Swets, 1974). According to this approach, any given physical stimulus produces a subjective experience (within the organism) called a discriminal process. Because the discriminal process is variable, repeated presentations of the same physical stimulus generate a discriminal distribution. The subject must then establish a criterion (or criteria) which defines a range of the discriminal distribution that the subject will attribute to a particular stimulus. Blough (1969) has shown that peaked generalization gradients would be found if instructions (for human subjects) or single-stimulus training (for animal subjects) caused them to create two symmetrical response criteria around the mean discriminal process produced by the training stimulus. Blough also noted that peak shift or asymmetrical gradients could be accounted for by assuming that the two criteria were independent. Specifically, a peak shift, such as predicted by Spence's theory, or an area shift, i.e. an asymmetrical gradient with enhanced responding on the side of S+ opposite the S−, would result if discrimination training caused the criterion on the S− side of S+ to be moved toward the mean of the discriminal distribution produced by S+ and had little effect on the opposite criterion. This would mean that stimuli just to the opposite side of S+ from S− would be more likely to produce a discriminal process that would be interpreted as S+ than those on the S− side or (in the case of peak shift) the S+ value itself.

The TSD approach to the study of generalization suggests the importance of some procedural variables which might not otherwise be considered. For example, although Spence's (1937) theory is unconcerned with the relative frequency of presentation of the training stimuli, according to TSD this is a major determinant of bias. When one stimulus occurs more often than the other, the criterion is shifted farther from the mean of the discriminal distribution produced by this stimulus and thus closer to the mean of the distribution caused by the other stimulus. Thus when in doubt the subject will be more likely to attribute a given sensation to the presentation of the more probable stimulus. This should result in a distortion of the post-discrimination generalizaton gradients, particularly in the region between the S+ and S− values where uncertainty should be greatest. In the present study, the S+ was presented three times as often as the S− (3:1 groups) or one third as often as the S− (1:3 groups). It was predicted that the 3:1 groups would respond more to stimuli between S+ and S− than would the 1:3 groups. Because our primary concern was with responding to stimuli intermediate between S+ and S−, we employed training values that were widely spaced on the (brightness) continuum. Using a procedure similar to that of the present study, Doll and Thomas (1967) had observed no peak shift in post-discrimination gradients when widely spaced wavelength stimuli were used. Even if no peak shifts are obtained, however, we can predict that the amount of area shift in the direction away from S− will be greater in the 1:3 groups, where the decision criterion (between S+ and S−) is presumably set closer to the mean of the S+ discriminal distribution.

In studying generalization along an intensity dimension it is important to recognize that the intensity of a stimulus could have a direct dynamogenic effect, as made explicit in Hull's (1943) concept of "stimulus intensity dynamism". In order to be certain that any differences obtained in this study could not be attributed to such a source, under each S+/S− ratio condition one set of groups was run with the S+ a brighter (i.e. more intense) light than the S− and another set was run with the S+ the dimer value.

Method

Subjects

The subjects were 40 male and 40 female students enrolled in introductory psychology courses at the University of Colorado.

Apparatus

Each subject was seated 60 cm in front of a 60-cm-square panel which was covered with black felt cloth. At approximately eye level, a 2.7-cm-diameter aperture was present. The subjects viewed a disc of white light projected onto a translucent glass screen behind the aperture. The light source was a light discrimination apparatus manufactured by the Lafayette Instrument Company (Model No. 14011), using a 60-W Sylvania clear Decor Lite (60CA9C/BL).

Seven different light intensities were selected so as to be .188 log units apart. The intensity values and their experimental designations were: stimulus value (SV) 1, 1.97 fL; SV 2, 3.04 fL; SV 3, 4.69 fL; SV 4, 7.23 fL; SV 5, 11.2 fL; SV 6, 17.2 fL; and SV 7, 26.5 fL. The experiment was conducted in a small dimly illuminated room. The light reflected from the disc when it was not illuminated was approximately .01 fL.

Procedure

After the subject was seated in front of the stimulus panel, the following instructions were read: "This is an experiment in brightness perception. A light will be presented repeatedly through a small hole in the screen in front of you. Each time it will be presented for five seconds and may have a different brightness. The first brightness is called the test brightness. Try to remember this brightness because you will have to distiguish it from all the other brightnesses. When you do recognize the test brightness say "same". If a subsequent brightness is different from the test brightness say "different". Remember, each time the light is presented it will stay on for only five seconds so try to respond while the light is on. I will tell you whether you are correct on the first few trials; then you will continue without further help. The first light is the test brightness. Keep its brightness in mind. For every light after that, say only "same" or "different". Any questions?"

Only questions dealing with the procedure were answered by the experimenter. Following any needed clarification of instructions, each subject was shown the appropriate S+ stimulus. Discrimination training was then carried out, consisting of 24 stimulus presentations. There were two major treatment groups in this experiment, one for which the S+ was presented 6 times and the S− was presented 18 times (1:3 groups) and one for which the S+ was presented 18 times and the S− was presented 6 times (3:1 groups). Within each of these groups, for half of the subjects S+ was SV 2; S− was SV 6; for the other half these designations were reversed. This resulted in a total of four groups: SV 2 (S+) 1:3, SV 2 3:1, SV 6 1:3 and SV 6 3:1. There were ten male and ten female subjects in each group.

After each correct response during discrimination training the experimenter said "correct" and after each incorrect response, the experimenter said either "no, that was different from the original" or "no, that was the same as the original", depending on the error. Next, generalization testing was initiated. With no interruption in the procedure, all subjects were shown six series of all seven stimuli, and feedback was no longer given. The stimuli were randomized within each series, and, as during discriminaton training, the interstimulus interval ranged unsystematically from 3-6 sec.

Results and Discussion

As a consequence of the wide spacing of the training stimuli, the discrimination between them proved to be quite easy. Furthermore, the number of errors made did not depend upon whether S+ was SV 2 or SV 6 (mean errors= 0.90 and 0.93, respectively) or whether S+ was presented six times or 18 (mean errors = 1.08 and 0.75, respectively). Analysis of variance indicated that neither of these differences was significant ($F < 1$).

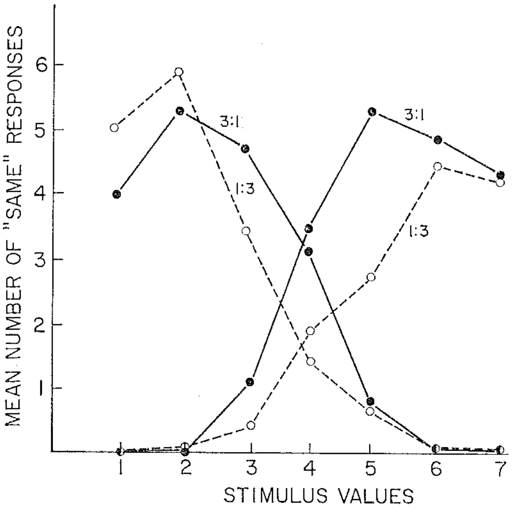

Figure 1. Mean stimulus generalization gradients of the four groups of subjects.

A gradient of stimulus generalization was constructed for each subject consisting of the number of "same" responses made to each of the test stimuli. The group mean gradients for the four groups are presented in Figure 1. For purposes of statistical analysis, for each subject responses to SVs 3, 4, and 5 were summed and these sums were entered into an analysis of variance with two factors, S+ S− ratio (i.e. 1:3 or 3:1) and stimulus values (i.e. SV 2 as S+ or SV 6 as S+). The effect of stimulus values was not significant ($F < 1$)

but the effect of S+/S− ratio was highly significant (F 1, 76 = 29.54, $p < 01$). Thus the prediction that the 3:1 groups would respond more to SVs 3, 4, and 5 was confirmed.

There was no peak shift from S+ to a more extreme value in this study. There was, however, evidence that the predicted difference in area shift was obtained. A measure of area shift was obtained from each subject, consisting of the ratio of number of responses to the stimulus on the S+ side of S+ (i.e. SV 7 or SV 1) divided by the number of responses to the stimulus on the S− side of S+ (i.e. SV 5 or SV 3). The group means of these area shift measures are presented in Table 1. Analysis of variance confirmed that the 1:3 groups had a significantly larger area shift (F 1, 76 = 21.02, $p<.01$).

Table 1: *Mean Area Shift for Each Group*

(2+)	(6−)	(2−)	(6+)
3:1	1:3	3:1	1:3
.84	2.10	.76	2.70

There is a suggestion in the data that the SV 6 3:1 group may be exhibiting a reverse peak shift, i.e. toward S−. Although the difference in number of responses between SV 5 and SV 6 is not significant ($t<1$) there is an indication of a reverse area shift, with relatively enhanced responding on the S− side of S+, in both the SV 3:1 and SV 2 3:1 groups. To determine whether this reverse area shift was significant, an analysis of variance was carried out, comparing the number of responses made by each subject to the two stimuli bordering on S+. The result indicated that significantly more responding was made, in these 3:1 groups, to the stimulus on the S− side (F 1, 39 = 11.68, $p<.01$). As is obvious from the figure, this did not occur with the 1:3 groups.

The finding of a reverse area shift seems entirely inconsistent with any prediction which might be generated on the basis of gradient-interaction theory. It can, however, be readily accommodated by the TSD model. Recall that according to this model, peak or area shift is attributed to the presence of asymmetrical decision criteria around the mean sensory effect of S+, with the criterion on the S− side normally closer than the criterion on the S+ side. Where the S+ and S− values are widely separated, as in the present experiment, and where the S+ appears far more often than the S−, this could result in the reverse of the normal state of affairs. That is the criterion on the S− side of S+ could actually shift farther from S+ than it would otherwise be, such that the criterion on the S+ side would now be the closer one, with a reverse peak shift (or area shift) a consequence thereof. Such a shift in response criterion toward S− is suggested by Doll and Thomas' (1967) finding that subjects trained to discriminate between two widely spaced wavelengths yielded flatter generalization gradients than did those given single stimulus training.

Further research will now be concerned with an attempt to determine the conditions under which a reverse peak shift (rather than just an area shift) can be shown, as well as to determine whether other experimental manipulations known to effect bias in traditional TSD experiments will have effects on generalization comparable to those observed here. In addition, it will be of interest to determine empirically whether feedback for correct (and incorrect) responses plays the same role as reinforcement does in animal studies of signal detection. In our procedure, since feedback occurred on every discrimination training trial, feedback frequency varied with the frequency of presentation of the two training stimuli. In a TSD study with pigeons, McCarthy & Davison (1979) examined these variables independently and determined that reinforcement frequency (and not signal probability) determined bias. By providing feedback on some but not all training trials we can determine whether the same principle applies in our paradigm.

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Erratum

Kammann, R. & Campbell, K. Illusory correlation in popular beliefs about the causes of happiness. *New Zealand Psychologist*, 1982, *11(2)*, 52-63.

An error appeared in lines 3 and 5 of the abstract of this article. The abstract should have read:

Experiment I demonstrates that, contrary to objective data, most people believe that happiness is strongly associated with good health, number of friends, country or small town residence, no disability, income, intelligence and type of work. When presented with case study data in which health, friends, country or small town residence, no disability, income, intelligence ment II perceived positive correlations. At the same time the majority of subjects correctly detected true postive, zero, and negative correlations for other factors not usually associated with happiness. There was no evidence in recognition test data that confirming instances were better encoded than disconfirming instances in any of the relationships presented. A simple associative trace model accounts for most laboratory results. Popular beliefs about happiness could arise either from a halo effect among "good things of life" or an overgeneralization from vivid short-term to pallid long-term effects. The unobservability of inner mental states in others sets the stage for definitional confusion and illusory correlation.