

or, as one possibility, the original learning may have been an inhibition of the incorrect response and the release of this inhibition, following depression of the trained hemisphere, made the incorrect response highly probable.

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Wavelength Generalization after Discrimination Learning with and without Errors

Abstract. Pigeons were trained to discriminate between 580 m μ (S+) and 540 m μ (S-) by procedures which resulted in either a large amount of responding to S- or in little or no responding to S-. A shift in the peak of a postdiscrimination generalization gradient, away from S-, was obtained only if the discrimination was learned with a large amount of responding to S-.

This report is concerned with two recently demonstrated phenomena that are related to the acquisition of a discrimination—the “peak-shift” in a postdiscrimination generalization gradient and “errorless” discrimination learning.

In his initial experiments on the peak shift, Hanson (1) trained pigeons to discriminate between two wavelengths, one correlated with reinforcement (S+) and one not correlated with reinforcement (S-). The discriminative stimuli were presented in successive alternation. Discrimination training continued until responses to S- had been extinguished below a predetermined criterion. The pigeons were then given a generalization test in which a series of 13 stimuli (including the original S+ and S-) were presented in a random sequence. The peaks of these gradients

were displaced away from S+, in a direction which also moved them further away from S-.

I have shown that pigeons can be trained to discriminate between different wavelengths and between different orientations of a line without responding to S-, if discrimination training begins immediately after the response to S+ has been conditioned, and if the difference between S+ and S- is progressively reduced from an initially large value to the smaller final value (2). This finding raised the interesting question of whether a peak-shift would be obtained after the training of a wavelength discrimination without responses to S- (errors).

The experiment was performed in a standard conditioning apparatus (3) in which the response key, which was typically operated by the pigeon pecking at it, could be transilluminated by any one of 15 Bausch and Lomb monochromatic stimuli whose half-widths were each less than 12 m μ . All of the stimuli were equated with respect to apparent brightness by the addition of neutral density filters whose values were derived from Blough's photopic visibility function for the pigeon (4).

The subjects were nine White Carneau male pigeons, with no prior experimental history, who were equally divided into three experimental groups. The first group of birds (Nos. G-148, G-188, G-196) received 14 sessions of training in which the response key was transilluminated by a light of 580 m μ . Responses were reinforced on a 1-minute variable-interval schedule. At the end of each minute a shutter interrupted the beam of monochromatic light for 2 seconds to prepare the birds for the generalization tests during which the 2-second time-out period would be used for changing filters. Responses to the dark key were never reinforced.

Another group of pigeons (Nos. G-173, G-219, G-209) was trained to discriminate between 580 m μ (S+) and 540 m μ (S-) with virtually no responses to S-. The details of the training procedure, which are described elsewhere (2), may be summarized as follows. Responses to S+ were reinforced on a 1-minute variable-interval schedule of reinforcement; S- was introduced at the start of the second session. (The first session was used to condition the key peck to S+.) The duration of S+ was 1 minute and S+ was presented at a constant intensity

throughout discrimination training. The duration and intensity of S-, however, were varied in three stages during the first discrimination session. During the first stage, the intensity of S- was held constant at a value that was 3.2 log units below the final intensity of S-, and the duration of S- was progressively increased from 2 seconds to 30 seconds over successive S- presentations. During the second stage, the duration of S- was held constant at 2 seconds and the intensity of S- was progressively increased from its initial value of -4.0 log units to its final value of -0.8 log units. During the final state, the duration of S- was progressively increased from 2 seconds to 1 minute. All three stages of varying S- occurred during the first discrimination session. Each bird received 14 sessions of discrimination training. The discriminative stimuli were always automatically changed during a 2-second time-out period that followed each S+ and each S- component; S+ and S- were successively alternated during the last five sessions. Birds G-173, G-219, and G-209 made 0, 1, and 4 responses to S-, respectively, during the 14 discrimination sessions.

The remaining three pigeons (Nos. G-202, G-203, G-165) were trained to discriminate between (S+) and (S-) by a procedure similar to Hanson's. During the first seven sessions, only S+ appeared on the response key. At the end of each minute the key was darkened for 2 seconds. Responses to S+ during these sessions, and during the subsequent discrimination sessions, were reinforced on a 1-minute variable-interval schedule of reinforcement. Discrimination training started at the beginning of the eighth session. The stimuli S+ and S- were presented alternately in random succession and were each followed by a 2-second time-out period. Each presentation of S+ lasted 1 minute. The duration of S- was also 1 minute unless responses to S- occurred. Each response to S- delayed the termination of the current S- for 30 seconds. This procedure insured that responses to S- could not be secondarily reinforced by the subsequent appearance of S+. Birds G-202, G-203, and G-165 made 1636, 1560, 3060 responses to S-, respectively, during seven discrimination sessions. More than 90 percent of each bird's responses to S- occurred during the first two discrimination sessions. During the last three discrimination

sessions, the rate of responding to S— was near zero for each of the birds in this group.

All sessions (except the first shaping session) were terminated after 25 reinforcements. Thus each bird received approximately the same number of reinforcements prior to its generalization test.

During the generalization test 15 stimuli (wavelengths of 490, 510, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 630, 650, 670 m μ) were each presented four times in a random sequence. Each stimulus was presented for 1 minute, after which the key was darkened for 2 seconds. During a generalization test no responses were reinforced.

Generalization gradients for each bird are shown in Fig. 1. Each panel shows the number of responses that were emitted to each of the 15 test stimuli. The numbers on either side of the vertical line, at 580 m μ (S+), represent the percentage of the total area above and below S+, respectively.

Figure 1 shows that the peaks of all but one of the gradients obtained from groups 1 and 2 (S+ training only, and discrimination learning without errors) occurred at 580 m μ (S+). The exception, G-188, may be due to a preference for 560 m μ which is suggested, to a lesser extent, by the gradients obtained from G-196, G-173, G-203, and G-165. Another common feature of the gradients obtained from groups 1 and 2 is the asymmetrical distribution of the area above and below S+. In each case there is more area below than above S+ (5).

The gradients obtained from group 3 (discrimination learning with errors) clearly differ from the group 1 and 2 gradients with respect to both the distribution of the area above and below S+ and the location of the peak. In all of the group 3 gradients there is more area above than below S+, and in two out of three cases the peak of the gradient is displaced away from S—. In both of these cases the peak occurred at 590 m μ instead of at 580 m μ (S+). Thus, the peak of a generalization gradient, obtained after discrimination training, is shifted away from S— only if responses were extinguished in the presence of S—. If a discrimination is learned without the extinction of responses to S—, no peak-shift is obtained. The gradients shown in Fig. 1 also show that the distribution of area above and below S+ may prove

to be more sensitive than the location of the peak as a measure of the effects of discrimination training. It was noted previously that a peak-shift was obtained in two out of three of the individual gradients of group 3, whereas a shift in the distribution of area above and below S+ appeared in all three gradients. Hanson's 1959 data (1) on a 40 m μ discrimination (S+ = 550 m μ ; S— = 590 m μ) also show that "area-shifts" occur in gradients which do not show a peak-shift. Only four out of eight gradients showed a peak-shift, but in each case, there was more area on the side of S+ that was away from S—, despite the fact that an asymmetry in the opposite direction was obtained in the control group.

The differences between the generalization gradients obtained after discrimination learning with errors and without errors appear to be related to other differences in performance that I have observed in experiments on

errorless discrimination learning. In one experiment, casual observations of numerous pigeons revealed that "emotional" responses such as wing-flapping and turning away from S— occur only if the discrimination had been learned with errors (2). It was also shown that chlorpromazine and imipramine impair discrimination performance only if a discrimination is learned with errors (6). If a discrimination is learned without errors, the behavior in the presence of S— remains calm and neither chlorpromazine nor imipramine produce any decrement in performance. These findings and the demonstration that the peak of a post-discrimination gradient is displaced away from S— only if the discrimination is learned with errors, suggest that S— functions differently in a discrimination trained without errors. If no (or few) responses to S— occur during the formation of discrimination, S— may function as a neutral stimulus. If,

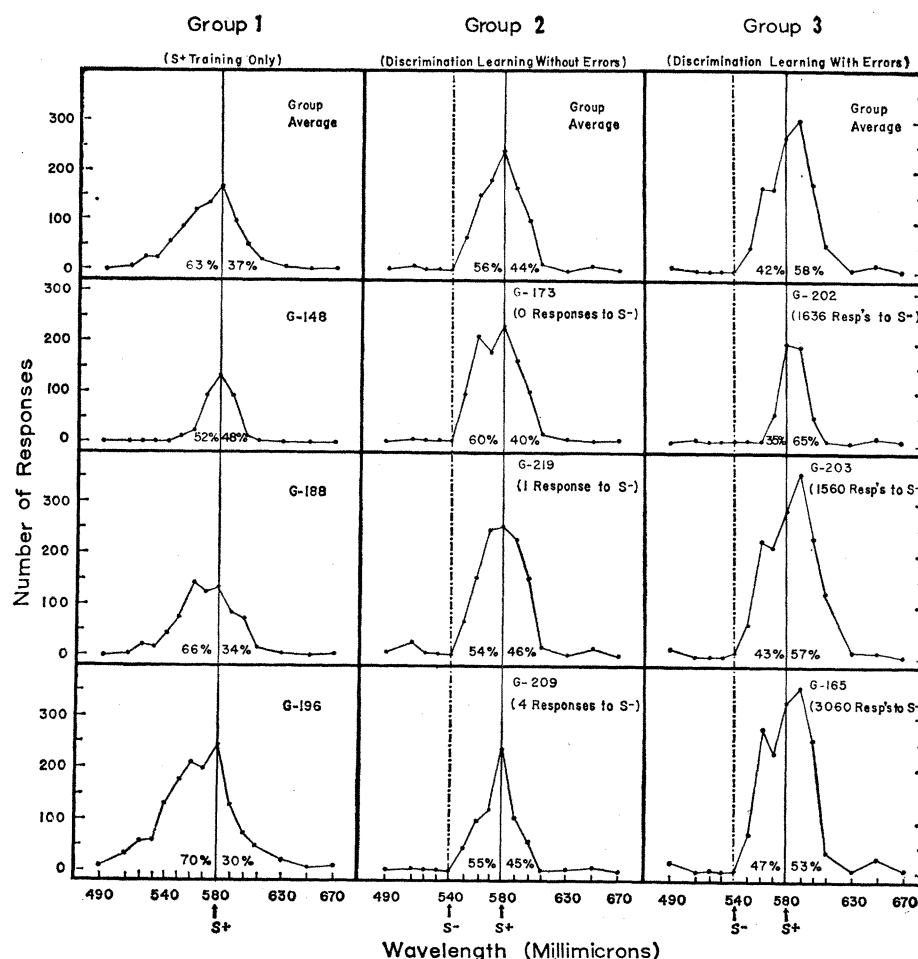


Fig. 1. Generalization gradients for each bird and average gradients for each group. Each point represents the number of responses emitted to one of the test stimuli presented in the generalization test. The number to the right and the left of the solid vertical lines represents the percentage of the total area under the gradient that lies above and below S+, respectively.

however, responses to S— are extinguished during discrimination training, S— may function as an aversive stimulus. According to this hypothesis, a shift of the peak or of the area of a generalization gradient, away from S—, would be described as a shift away from an aversive stimulus.

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4. D. B. Blough, *J. Opt. Soc. Am.* **47**, 827, (1957). The values of the neutral density filters were computed as follows. On the basis of Blough's table of photopic sensitivity, a zero increment in density was assigned to the stimulus at which the least sensitivity was obtained (440 mμ) and the largest increment was assigned to the stimulus at which the most sensitivity was obtained (560 mμ). These values were then corrected for the different transmittances of each monochromatic filter. The decrements in intensity at each stimulus were: 490 mμ, -0.3; 510 mμ, -0.5; 520 mμ, -0.6; 530 mμ, -0.6; 540 mμ, -0.8; 550 mμ, -0.8; 560 mμ, -0.9; 570 mμ, -1.0; 580 mμ, -1.0; 590 mμ, -0.9; 600 mμ, -0.8; 610 mμ, -0.7; 630 mμ, -0.5; 650 mμ, -0.1; 670 mμ, 0.0.
5. It should be noted that the asymmetrical distribution of area above and below S+ is not due to the fact that a different number of stimuli above and below S+ were used in the generalization test (eight below and six above S+). Asymmetrical distributions of area would also be obtained if the number of responses to the two lowest stimuli (490 and 510 mμ) were omitted from the calculation of area.
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7. I thank D. B. Moody and E. Richardson for their valuable assistance. This research was supported by NIH grant MH-05770-02 and NSF grant GB-1629.

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I.Q., Genetics, and Culture

I was rather surprised to read in *Science* (13 Dec. 1963, p. 1477) a report entitled "Genetics and intelligence: A review," by L. Erlenmeyer-Kimling and L. F. Jarvik, purporting to show that "Individual differences in behavioral *potential* reflect genotypic differences; individual differences in behavioral *performance* result from the nonuniform recording of environmental stimuli by intrinsically nonuniform organisms" (*italics in original*). Whatever the truth of the report's thesis, if any, it cannot be supported by the type of correlation data presented.

In the first place, the nature of environmental influences on intellectual development have by no means been elucidated, and it does not follow that individuals reared together

were subjected to similar effective environmental influences or individuals reared apart to dissimilar ones. At the risk of overstating the obvious, I give two examples of the difficulty: rival siblings may be exposed to very different environments though reared in the same home and surroundings, and placing a Negro child in the home of a white foster parent will not make the environment for that child similar to that of his foster brothers and sisters. In the second example, the differences will arise in part from skin color, which is genetically determined, but will be caused by the cultural implications of that color, not by genetic limitations associated with it.

Secondly, there is a long and unsettled controversy over how intellectual *potential* is to be measured. I personally suspect that I.Q. and other tests measure to a considerable degree the extent of cultural (environmental?) conformity between those who construct the tests and those who take them. An intelligent Eskimo would fail I.Q. tests, but I suspect that Erlenmeyer-Kimling and Jarvik would fail to survive an Arctic winter. Since a reliable, independent measure of intellectual potential does not exist, the matter cannot be settled. However, to me the pertinent experiments are those which demonstrate that performance on I.Q. tests is altered by changes in environment.

In the same issue (p. 1436) appears a confusing long article with a similar thesis by J. Hirsch, who sets the physiologists and the behaviorists in a windmill which he labels "believe in the initial uniformity of individuals" and then charges them pell-mell with the lance of genotypic uniqueness. He then attacks "reductionism," the fallacy of which he states to be the assumption of a "one-one relation between different levels of organization," and on the next page discusses the one-to-one relation between genes and behaviour.

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If Daniel meant to say that our data do not establish our hypothesis, then he is, of course, correct; no quantity of data ever established any hypothesis. If he really meant to say that the data do not support our hypothesis, then we can only refer

him and other readers to our report and chart.

Daniel also points out that rival siblings may be exposed to very different environments though reared together. Even if this were true for relevant environmental variables, the data still support our hypothesis.

We should like to reiterate the concluding paragraph of our report, in which the important concept of the "norm of reaction" is briefly discussed: "We do not imply that environment is without effect upon intellectual functioning; the intellectual level is *not* [*italics in original*] unalterably fixed by the genetic constitution." Just as in the example of phenylketonuria cited in the same paragraph, alterations in performance on intelligence tests following changes in environmental stimulation illustrate the concept of the "norm of reaction."

Incidentally, neither an Eskimo nor anyone else, intelligent or unintelligent, could "fail I.Q. tests."

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Temperature of Metallic Objects in Space

The report by C. Butler and R. Jenkins (1) on "Temperature of an iron meteoroid in space" shows an application of thermodynamic theory similar to that used some 6 years ago to predict the solar heating of artificial satellites (2). Their report generally agrees with the theory (later confirmed by actual measurements on satellites) thus previously developed for temperatures of a solid body in space and in full sunlight. However, they have neglected the factor, for bodies near the earth, of the shadow of the earth. Consideration of this neglected factor would seem to modify very seriously their categorical conclusions that "the equilibrium temperature of an iron meteoroid just before entering the earth's atmosphere will be close to 90°C," and that any assumptions that meteoroids are "quite cold" just before entering the atmosphere necessarily contradict thermodynamic theory.

If a meteoroid enters the earth's atmosphere at night (and such is the