was required to again stop firing; presumably a subthreshold concentration of the drug was still present in the tissues. Equimolar doses of chlorpromazine did not affect the firing of the LSD-sensitive units in the raphe.

Our results suggest that those units which respond to injections of LSD by a cessation of spontaneous firing are serotonin-containing neurons since their location corresponds precisely to those areas of the midbrain where these cells are clustered. The fact that cells in the raphe are inhibited after injections of LSD is in accord with expectations based on the biochemical data showing a decreased turnover of serotonin after administration of this drug. However, since there may also be some neurons of other types in the dorsal and median raphe nuclei, a definitive demonstration of specificity must await studies which combine the methods of fluorescence histochemistry and the identification of an electrode tip within the area of a single cell. Nevertheless, it is important to note that an inhibitory effect on neuronal firing is not universal after the small parenteral doses of LSD used; in fact, none of the cells observed outside the raphe ceased firing in response to the drug.

It should not be assumed that the effect of LSD on raphe units is a direct one. It has been suggested that LSD may affect serotonin-containing neurons by an indirect, neuronal feedback mechanism (*8*). This speculation is based in part on the similarity between certain behavioral effects of LSD (*13*) and those seen after stimulation of serotonin-containing neurons (*14*). In both circumstances there is a failure of habituation to repetitive sensory stimuli. One explanation for this common behavioral effect would be that LSD acted "like" serotonin at a postsynaptic site. This could result in an indirect inhibition of the serotonin-containing neurons by a compensatory neuronal feedback mechanism. The inhibition of raphe neurons could also be due to complex actions of LSD at other neuronal sites. In any event, our data do not discriminate between the possibilities of a direct or indirect action of LSD on the serotonin-containing neurons.

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1 July 1968

Taste Stimuli: A Behavioral Categorization

Abstract. *The selective patterns of generalization to various chemicals, obtained in rats after radiation-induced gustatory-avoidance conditioning against single chemicals, were used to evaluate qualitative similarities among taste stimuli.* DL-*Alanine, glycine, and sodium saccharin were classed together, but not with* D-*glucose or potassium chloride. Groupings such as these may serve as a basis for determining the dimensions along which taste quality is represented.*

In contrast to what is known about other sensory stimuli, knowledge of how taste stimuli should be classified is limited. For example, in audition the physical dimension of frequency bears an orderly relation to judgments of tonal quality and to the neural responses of the auditory receptor system. Although limited correlations have been proposed between the physical characteristics of chemicals and human description of taste quality (*1*), the appropriate dimensions with which to scale taste stimuli are not known (*2*). Neurophysiological data suggest that taste quality may be represented along several dimensions (*3*). The available behavioral data, although few in number, support these neural observations (*3, 4*).

We now present a method which gives information on how animals classify taste stimuli. Ionizing radiation is used to create a strong and sustained gustatory aversion toward any one of a variety of chemicals (*5*). Animals are conditioned to reject a selected concentration of a specific chemical, the primary conditioning solution (PCS) (*6*). We assume: (i) the PCS becomes the quality standard against which the animals compare other solutions; (ii) the test solutions will be aversive, that is, associated with the PCS, as long as their taste to the animal is qualitatively similar to the PCS (*7, 8*); (iii) the magnitude of rejection indicates the degree of similarity in taste between the test solution and the PCS (*9*). When animals are tested for rejection of solutions of the same chemical as the PCS, the pattern of rejection over the concentration range tested constitutes an intrachemical generalization function.

We evaluated the qualitative similarity between two PCS's by cross-generalization studies in which the intrachemical generalization function for each PCS is compared with another function, the interchemical generalization function. The interchemical generalization function is obtained by measuring the rejection of the same solutions of one PCS chemical in animals conditioned to reject the other PCS. The more the functions of each generalization pair resemble one another, the closer the qualities of the two PCS's will be (Fig. 2).

Male Sprague-Dawley rats (Charles River, 150 to 200 g) were trained to drink their normal daily supply of fluid during a 30-minute session during which distilled water was offered every 40 seconds for 20-second periods. Fluid consumption was measured by counting licks. Avoidance was conditioned only after the animals demonstrated a high (>100 licks per 20 seconds) and sustained drinking level throughout the session. The conditioning was done dur-

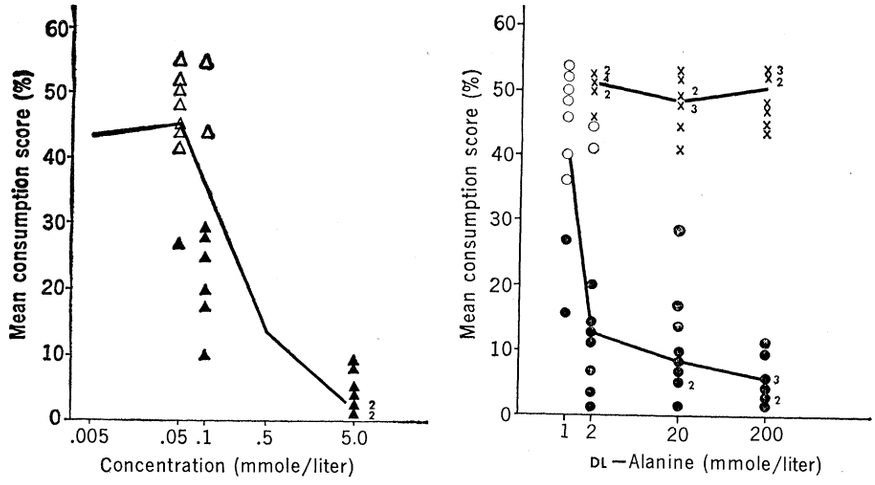

Fig. 1. Intrachemical generalization functions. Rejection was measured at the conditioning and lower concentrations in descending order. Open symbols, consumption score not significantly different from 45 percent; closed symbols, significantly less than 45 percent. Inset numbers indicate several scores at same value. Sodium saccharin generalization (left). Solid line, median values for seven rats tested over range from 5.0 to 0.005 m*M* solution. Triangles, individual values of eight additional animals tested at 5.0, 0.1, and 0.05 m*M* solution. DL-Alanine generalization (right). X, water-water controls run 1st day after conditioning; circles, individual alanine-water values run 2nd day; solid line, median value of all animals.

ing one session in which the presentation scheme was modified by alternating distilled water with a solution novel to the animal [for example, per liter: 5 mmole of sodium saccharin (U.S.P.), 200 mmole of DL-alanine, or glycine (National Research Council)]. Twenty minutes before the start of this conditioning session the rats were exposed to 200 r of cesium-137 gamma-radiation (80 r/min) for 2.5 minutes. The animals stopped drinking the novel sodium saccharin, on the average, after six presentations but continued to drink the familiar distilled water.

On the 1st or 2nd day after conditioning, the animals were tested for rejection of the PCS or of other chemical solutions. A descending series of three or four concentrations was used. Each concentration was offered alternately with distilled water for six water-solution or solution-water pairs. Solution intake was scored as a percentage of total fluid intake of each pair consumed. For each animal at each concentration a mean consumption score significantly less than 45 percent ($P<.05$, Student's t) was defined as rejection. A generalization threshold was taken to lie between the lowest concentration of solution at which at least 50 percent of the rats reject the solution and the next lower concentration tested (*10*).

Intrachemical generalization functions are shown in Fig. 1. Fifteen animals conditioned to avoid solutions of 5 m*M* sodium saccharin (Fig. 1, left) displayed a generalization threshold of 0.1 to 0.05 m*M*, whereas nine rats conditioned against 200 m*M* DL-alanine (Fig. 1, right) showed a threshold of 2 to 1 m*M*. These threshold values for both chemicals approximate preference thresholds (*6*).

People usually assign a high sweetness rating to our conditioning concentrations of sodium saccharin, DL-alanine, and glycine (*11*). Rats prefer these solutions over distilled water (*6*), but do they classify them as being qualitatively similar? Our studies of cross generalization (Fig. 2) demonstrate that they do. The sodium saccharin interchemical generalization function for rats trained to reject DL-alanine was similar to the sodium saccharin intrachemical function. Likewise, the DL-alanine interchemical generalization function for animals trained to reject sodium saccharin was similar to the DL-alanine intrachemical generalization function. Comparable close cross generalizations between sodium saccharin and glycine and between DL-alanine and glycine were found.

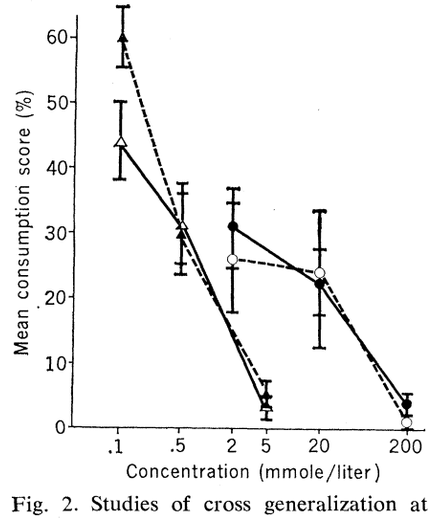

Fig. 2. Studies of cross generalization at conditioning and two lower concentrations of sodium saccharin (triangles) and DL-alanine (circles) in rats conditioned to avoid 5 m*M* sodium saccharin (open symbols) or 200 m*M* DL-alanine (closed symbols). Solid lines, intrachemical generalization functions; dotted lines, interchemical generalization functions. Bars indicate mean ± standard error.

Animals conditioned to avoid one chemical do not generalize to all other novel solutions (*12*). For example, rats trained to avoid solutions of 200 m*M* DL-alanine failed to reject 1*M* D-glucose or 100 m*M* KCl. Those conditioned to avoid 5 m*M* sodium saccharin did not reject 100 m*M* KCl and displayed only a slight tendency to reject 100 m*M* D-glucose. The common rejection of sodium saccharin, DL-alanine, and glycine suggest that they appear very similar in quality to the rat. Although glucose is also preferred by rats and is judged sweet by people, the rats did not group it in the same class as sodium saccharin, DL-alanine, or glycine. Preference is not the same as qualitative similarity.

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20 June 1968

Crescentic Landforms along the Atlantic Coast of the United States

Dolan and Ferm (*1*) suggest a geometric relation between groups of crescentic coastal landforms along the Atlantic coast of the United States. According to them the various groups or orders range from beach cusplets through beach cusps, storm cusps, giant cusps, secondary capes, the Carolina Capes and Cape Kennedy, and Cape Hatteras to the southern tip of Florida and finally to 90° of latitude. The suggested relation is that the tip-to-tip spacing of each successively larger group increases by a power of 10. Shallow-water deformation by waves and associated inshore current cells are stated to be factors governing the three smallest groups of features, while it is inferred that the larger groups reflect regional control by a series of secondary rotational cells that develop along the western edge of the Gulf Stream.

We believe that the report (*1*) errs on two related points, and that on a third and more important point it deserves to be seriously questioned. The erroneous related points are made in connection with the speculation that the Carolina Capes, Cape Kennedy, and larger orders of coastal landforms may reflect regional control established by a series of secondary cells that develop off the Gulf Stream. These speculations ignore two facts:

1) Cape Fear and Cape Kennedy are known to be controlled by geologic structures. In the case of Cape Fear, the controlling structure, Cape Fear Arch, is one of the largest and most obvious features on geologic maps of the southeastern United States.

2) From what is known from study of the Gulf Stream in the open ocean (*2*), there is no suggestion of regularity of eddies off its western edge such as one would expect if these eddies were to control evenly spaced coastal landforms. If regularity of inshore eddies does exist, it would be more plausible to ascribe this regularity to control by the Carolina Capes rather than to attribute these topographic features to such regularity.

The final and most important point on which the report must be questioned is the power-of-10 relation in size between successive orders of crescentic features. The authors' (*1*) Fig. 2 clearly implies marked discontinuities between the smaller size groups. No crescentic landforms having tip-to-tip spacings of 2 to 8 m, 25 to 70 m, 120 to 700 m, or 1200 to 8000 m are reported. In our experience, and apparently in that of Cloud (*3*) and of the many workers to whom he refers, this striking size distribution has been missed.

Let us assume for the moment that Dolan and Ferm's relation (*1*) does exist. Readers should ask what would its implications be regarding the statement that shallow-water deformation by waves and associated inshore current cells govern the first three orders of these features. There are no discontinuities in wind energy or duration, or in fetch over which winds blow from storm centers to points at which day-to-day wind conditions are encountered. The factors that control inshore waves and currents range through continuous spectra that could hardly be manifested by a series of landforms of discontinuous size distribution.

It seems to us that the conclusion of Dolan and Ferm (*1*) regarding a power-of-10 size relation between successive orders of crescentic features was based on an unhappy coincidence of observations insufficient in number or in their distribution in time, and that the conclusion is invalid.

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14 May 1968

The point of our report [*Science* **159**, 627 (1968)] appears to have been missed by Ball and Newmann. Our summary read:

> The central *questions regarding* the *origin* of these features are: (i) Do the features reflect and are they controlled by interacting processes, including both planetary currents and shoaling and breaking waves? (ii) *Are these* interacting processes continuous in nature? [The italics are added.]

Questions concerning the origin of landforms are commonly subject to debate, especially when the topic is as diffuse as coastline landforms along the margins of a continent. Possible explanations are surely more numerous than those we mentioned; our object was not to offer a definitive explanation of the origin of coastline landforms, but rather to observe relations between form and chronology and to raise questions about these relations.

As for their mention of "unhappy coincidence," we can only reiterate that our total number of observations was 750, that most were made along the Outer Banks of North Carolina, and that the modes came out approximately as shown. Whether our finding was happy or unhappy, or a coincidence, can be determined only by further sampling.

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