in their qualities become too great, there is no longer any interaction at all.

If the analogy holds between hearing and taste, it should be possible to repeat this experiment on the tongue and to find out whether there is any difference in the interaction between the four different primary taste qualities and the two added qualities of heat and cold. An experiment was therefore performed in which a lucite plate with two openings, as shown in Fig. 2, was placed on the surface of the tongue, with the openings on the left and right sides. The openings were 4 mm long, 1.5 mm wide, and 15 mm apart. Each was connected to a plastic tube, which provided a constant flow of water of about 36°C at about 1.5 ml/sec. A specially constructed electrodynamically driven valve (*4*) permitted the constant flow to be replaced by either a solution or by water of different temperature, at the same streaming velocity and without the introduction of additional changes. The solutions and the heated or cooled water were presented as stimuli to the tongue for 1 second. Each stimulus could be presented once, by the pressing of a button, or repeatedly every 10 seconds, according to the preference of the subject. A special arrangement permitted the concentration of the solutions to be controlled instantaneously over a range of 1 to 10 by the rotation of a dial. This was an important feature, because for good observations it was necessary to adjust the sensation magnitude so that it was equal on the two sides of the tongue. Care was taken to have the whole set-up for the two sides of the tongue equal, but since the sensitivity of the tongue for taste and temperature changes might be different on the two sides, the sensation magnitudes had to be matched before each observation.

Each session was begun by presenting single stimuli alternately to one and the other side and matching their sensation magnitudes. When the stimuli to the two sides are the same, this adjustment is not difficult; but when the stimuli on the two sides are different, for instance, bitter and heat, then the adjustment takes time and can be done only by approaching the mean adjustment by bracketing, from above and below. After the stimuli to the two sides were matched, they were presented to both sides "simultaneously," but with the means available to introduce a slight positive or negative time delay. The subject reported whether he localized a single sensation midway between the two openings or whether there were two separate sensations just below each opening. After a week of training in localization, both acoustical and gustatory, the subjects had no difficulty deciding whether there was interaction between the two sides or not.

When the same stimulus was presented on the two sides, the sensation was always localized in the middle, provided the sensation magnitudes had been matched. But when two different stimuli were presented to the two sides, there was sometimes an interaction and sometimes not. Bitter, warm, and sweet seemed to interact among themselves, and so did sour, cold, and salty. They seemed to form two clear groups of stimuli that had some quality in common. There was no interaction between the members of the two groups. We tried all 15 combinations of the four primary tastes plus heat and cold. We found it advantageous to use weak stimuli, since they gave a more definitive picture. This was especially true with cold, since for many observers cold may produce pain, which then inhibits interaction. Naturally, there is no single pure primary taste stimulus to be obtained. All the solutions used have some side tastes, more or less a combination of several primary tastes. Only heat and cold seem to be pure primary stimuli. In our experiments we used quinine for bitter, cane sugar for sweet, hydrochloric acid for sour, and sodium chloride for salt stimuli. Three well-trained subjects were used and for each of them the solutions were adjusted for their individual thresholds.

Our results are shown in a six-point scheme in Fig. 3 which shows clearly that the six primary stimuli fall into two well-separated groups, indicated by the two triangles.

Some experiments along different lines and which will be reported elsewhere (*7*) resulted in the same grouping, namely, bitter and sweet versus salty and sour. It will be of interest, therefore, to determine the anatomical and physiological correlates of this grouping.

Since the lateralization phenomenon has been helpful in the analysis of the grouping of taste sensations, it is hoped to apply a similar technique to olfaction. Presenting each nostril with a different odorant and observing its localization may lead to a division of olfactory stimuli into similar groups.

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Depth Perception in Sheep: Effects of Interrupting the Mother-Neonate Bond

Abstract. *Twin lambs were divided into two groups: an unmothered group consisting of one of each pair of twins separated from its mother at birth, and a mothered group consisting of the other member of each pair reared by its mother. Lambs in both groups were placed individually on a "visual cliff" once every hour. In all instances lambs in the mothered group exhibited "cliff avoidance" behavior before those in the unmothered group. In another experiment, mothered lambs were fitted with translucent goggles for half the time required by unmothered lambs, matched on the basis of sex and birth weight, to acquire depth perception. Again, in all instances the mothered, goggled lambs avoided the cliff before the unmothered lambs.*

There is ample evidence (*1*) that interference with the formation of the mother-neonate bond in sheep and goats produces remarkable effects on later social and other behavior. Walk and Gibson (*2*) reported extensive use of a "visual cliff" in investigating the cues for depth perception, as well as the development of perceptual skills, in various animals. These authors noted the survival value of the closely related development of the abilities to perceive depth and to be mobile. They found that in sheep and goats, animals which are able to walk moments after birth, avoidance of an apparent cliff occurred quite early. Our discovery of individual differences in the rate of development of avoidance behavior in lambs led to the research described herein.

A smaller version of the visual cliff of Gibson and Walk was constructed with a pane of glass (46 × 92 cm), enclosed on all sides and at the top with solid painted wood, and lighted from beneath to minimize glare. Immediately beneath the glass and at one end was a wooden platform, 15 × 46 cm. Under the remainder of the glass was an "apparent drop" of 1 meter. The stimulus for movement onto the "drop" was the overhead intersection of the planes of the wall and the ceiling of the enclosure. Collias (*3*) reported the tendency of the newborn lamb to orient along a plane or intersection of planes and to move in relation thereto until stopped by some obstruction. The youngest lambs behaved in this manner without regard to the apparent drop beneath their feet. As they grew older, however, they began to exhibit the "characteristic stereotyped behavior" of Gibson and Walk: "[The lamb] would back into a posture of defense, its front legs rigid and its hind legs limp. . . . Despite repeated experience of the tactual solidity of the glass the animals never learned to function without optical defense" (*4*).

Table 1. Trials on which mothered and unmothered twin lambs developed depth perception.

Pair	No. of trials	
	Mothered	Unmothered
1	2	3
2	3	11
3	5	10
4	3	5
5	2	5
6	1	4
7	1	2
8	5	7
9	3	5
10	1	4
11	7	8
12	3	12
13	5	7

Table 2. Ages at which mothered lambs fitted with goggles and unmothered pairmates developed depth perception.

Pair	Age (hr)	
	Goggled and mothered	Unmothered
14	7.5	13
15	3	6
16	6	12
17	5.5	7
18	2.5	5

For our experiments we used lambs of registered Suffolk ewes bred by the same Suffolk ram. Thirteen sets of twins were used in the first experiment. Mothered and unmothered groups were made up by alternately assigning first- or second-born siblings to the two groups. Mothered lambs were left with the ewes in individual indoor stalls. Lambs in the unmothered group were taken from their mothers immediately after birth, cleaned, and fed colostrum from their own mothers or from another lactating ewe until the depth perception tests were completed. Once every hour the lambs in both groups were placed individually in the testing apparatus and observed through a peephole in the enclosure in the end away from the platform where the animal was standing. "Passing" the test was defined as staying on the 15 × 46-cm platform for 3 minutes without placing any two feet simultaneously on the pane of glass over the "vacant" area.

In every instance the mothered member of the twin pair began to avoid the cliff on an earlier trial than did the unmothered member of the pair (see Table 1). Some mothered lambs passed on the first trial. The trials at which the mothered group perceived and reacted to depth ranged from trial 1 to trial 7; for the unmothered animals the range was from trial 2 to trial 12.

In the second experiment, goggles were placed on the mothered lambs so as to give those in the unmothered group some advantage. Two groups of five lambs each were selected, this time not twins, but each from a different mother. Pairs were matched on the basis of sex and birth weight. Pairing was accomplished by first selecting a lamb for the unmothered group and then assigning the next lamb born of similar sex and birth weight to the goggled, mothered group. The unmothered lamb was taken from its mother and treated in the same way as the lambs in the unmothered groups of the previous experiment.

Lambs remaining with their mothers were fitted with translucent plastic goggles which prevented patterned vision. The goggles were held in place with rubber bands which did not hinder sucking or other activities. The goggles were left on while the lamb remained with its mother in an individual indoor stall, and were worn for a period of time equal to half the age at which its matched pairmate displayed adaptive reaction to the testing apparatus. For example, in Table 2, pair 16, the unmothered lamb did not successfully avoid the vacant area of the glass pane until its 12th trial at the age of 12 hours. The mothered member of pair 16 thus wore goggles for 6 hours. When the goggles were removed, this lamb successfully avoided the glass immediately, on the first trial, without previous experience on the visual cliff apparatus. The mothered lambs in pairs 15 and 18 also avoided the cliff on the first trial.

As in the first experiment, all the mothered members of the matched pairs exhibited avoidance behavior at an earlier age than the unmothered members of the pairs.

The results of these experiments present striking evidence that some unspecified elements in the mother-neonate relationship are closely related to the development of perceptual skills, particularly depth perception, as well as subsequent adjustive avoidance behavior.

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