THE EFFECT OF ADDED LOADS UPON THE GEOTROPIC ORIENTATION OF YOUNG GUINEA PIGS

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I

It has been shown in several instances that mammals, while progressing over a surface inclined at angle $\alpha$, orient upward in a way such that the relation between the angle of orientation $\theta$ and $\log \sin \alpha$ is sigmoid in character, when $\theta$ represents the angle at the intersection of an oriented path with the base of the inclined surface. In the cases of young rats (2, 3, 4), and mice (1, 5), the curve is continuous over the entire range of stimulation. A difference appears in the plotted data in the cases of young guinea pigs (7) and adult white rats (6). The functional connection between $\theta$ and $\log \sin \alpha$ is again sigmoid in character, but in both instances the curves are discontinuous; each curve is compound, being made up of two sections. In one investigation, including two groups of six and eight young guinea pigs respectively (7), the junctions of the two sections occurred in the region of $\alpha = 45^\circ$. In the present investigation the break occurred at a lower inclination, in the region of $\alpha = 35^\circ$. With the adult white rats the disjunction occurred at $\alpha = 55^\circ$ (6). With both young guinea pigs and adult white rats it was observed that within the range of values corresponding to the discontinuous parts of the plotted curves the mode of progression over the plane changed from walking to hopping (5, 6). Since the distribution of muscular tensions involved in hopping must necessarily differ from that involved in walking, the change in the mode of progression may be regarded as determining the change in the relation of $\theta$ to $\alpha$.

The conditions which determine the change in mode of progression, and therefore the location of the breaks in the curves relating $\theta$ to $\alpha$, are as yet undefined; but it is hoped that by testing animals under the
ADDED LOADS AND GEOTROPIC ORIENTATION

effect of added loads of varying magnitude, attached so as to effect different muscular groups, information may be obtained which will throw light upon this specific problem as well as upon the general problem of proprioceptive function. The present experiment was designed to show the effect of an added load of constant relative mass upon the geotropic conduct of young guinea pigs.

II

A plane surface 84 cm. by 124 cm., covered by a tightly stretched piece of heavy 3 mm. wire mesh was hinged at one end so that the inclination could be varied. It is to be noted that the plane used in the present instance was covered with screen of a larger mesh than that used in the earlier experiment (7). The larger mesh was found to be desirable because it afforded a much more secure foothold to a test animal and completely eliminated slipping and falling at the higher angles of inclination. The technique of observing and recording the trails of the various inclinations of the plane was the same as that employed in previous investigations and has been described elsewhere (7).

Four litter-mates were used for this series of measurements. Experimenting commenced when the animals were 4 days old and was completed in the next 6 days. In experiments of this type the very young guinea pigs are preferable to older animals because they are much more active on an inclined surface. Furthermore, the behavior of the young is much less variable than that of older guinea pigs. For these reasons it is desirable that a series of tests be completed as soon as possible, taking into consideration, however, the fact that the young animals are very susceptible to the effects of fatigue. In this experiment ten trails for each animal, both with and without added load, were collected at each of several inclinations ranging from $\alpha = 15^\circ$ to $\alpha = 60^\circ$ by steps of $5^\circ$.

The loads carried by the animals were made of saddle-like pieces of sheet lead, so constructed and attached that the normal position of the center of gravity of an animal's body was not greatly changed by the addition of the load.

A saddle of lead equal in weight to 10 per cent of the body weight of the animal carrying the load was attached to the back at a point midway between the fore and hind legs. A piece of adhesive tape served to hold the load securely in place. The experiment was carried on in complete darkness. Spots of luminous paint on the edges of the plane served as reference points, and a spot of luminous paint attached to the animal on the plane enabled the observer to record the path described by the animal in its movements. During the periods of experimentation the room temperature varied from 19 to 24°C. The readiness with which young guinea pigs react on an inclined plane seems to be greatly influenced by the temperature of the room in which an experiment is being carried on. An approximate temperature of 22°C. seems to be desirable for experiments of this type.
III

Table I presents the measurements of upward orientation $\theta$ for the four young guinea pigs at several inclinations $\alpha$ of the plane of progression.

**TABLE I**

Data for Four Guinea Pigs without Added Load. Each Value of $\theta$ Represents the Mean of 40 Observations

<table>
<thead>
<tr>
<th>$\alpha$ (degrees)</th>
<th>$\theta$ (degrees)</th>
<th>P.E. $\theta$ (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>47.8</td>
<td>1.03</td>
</tr>
<tr>
<td>20</td>
<td>54.5</td>
<td>1.02</td>
</tr>
<tr>
<td>25</td>
<td>56.6</td>
<td>1.26</td>
</tr>
<tr>
<td>30</td>
<td>59.5</td>
<td>0.86</td>
</tr>
<tr>
<td>35</td>
<td>60.7</td>
<td>0.91</td>
</tr>
<tr>
<td>40</td>
<td>65.8</td>
<td>0.89</td>
</tr>
<tr>
<td>45</td>
<td>72.8</td>
<td>0.74</td>
</tr>
<tr>
<td>50</td>
<td>77.4</td>
<td>0.75</td>
</tr>
<tr>
<td>55</td>
<td>80.9</td>
<td>0.52</td>
</tr>
<tr>
<td>60</td>
<td>86.1</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**TABLE II**

Data for Four Guinea Pigs with Added Load Equal to 10 Per Cent of Body Weight. Each Value of $\theta$ Represents the Mean of 40 Observations

<table>
<thead>
<tr>
<th>$\alpha$ (degrees)</th>
<th>$\theta$ (degrees)</th>
<th>P.E. $\theta$ (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>58.8</td>
<td>1.18</td>
</tr>
<tr>
<td>20</td>
<td>65.1</td>
<td>0.86</td>
</tr>
<tr>
<td>25</td>
<td>64.0</td>
<td>0.88</td>
</tr>
<tr>
<td>30</td>
<td>67.9</td>
<td>0.78</td>
</tr>
<tr>
<td>35</td>
<td>69.7</td>
<td>0.76</td>
</tr>
<tr>
<td>40</td>
<td>75.2</td>
<td>0.79</td>
</tr>
<tr>
<td>45</td>
<td>77.3</td>
<td>0.74</td>
</tr>
<tr>
<td>50</td>
<td>84.6</td>
<td>0.52</td>
</tr>
<tr>
<td>55</td>
<td>85.4</td>
<td>0.42</td>
</tr>
<tr>
<td>60</td>
<td>89.2</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table II summarizes a series of tests upon the same animals at corresponding values of $\alpha$ in which each animal carried a load equal to 10 per cent of its body weight. The testing of an animal with the...
ADDED LOADS AND GEOTROPIC ORIENTATION

added load at a given value of \( \alpha \) followed the testing of the animal without the load at that inclination. Because fatigue was found to be an influential factor in the performance, at least 30 minutes was allowed to elapse between any two tests of the same animal. Each value of \( \theta \) in Tables I and II is the average of 40 observations.

![Graph showing angles of orientation with and without added loads](image)

**Fig. 1.** Angles of orientation with and without added loads of a group of four animals. The angles of orientation without added load, resulting from an earlier experiment (7) involving two groups of animals, have been plotted in this figure to show the agreement between three independent series of observations. In these latter series the breaks in the plotted functions appeared in the region of \( \alpha = 45° \).

The mean values of \( \theta \) are plotted directly against \( \alpha \) in Fig. 1. The function which relates \( \theta \) to \( \alpha \) is clearly curvilinear, and discontinuous with a break at \( \alpha = 35° \). That the added load was a definite factor in determining the orientation of the guinea pigs on the inclined surface is
most apparent. At all values of $\alpha$ the $\theta$ values are significantly higher for orientation with added load than for orientation without the load. It may be noted that the values of $\theta$ become more nearly equal under the two sets of conditions as $\theta$ approaches 90°. This is clearly indicated in all the figures and would be a reasonable prediction, since both with and without added load the value of the response approaches 90° as a limiting value. The data collected in an earlier experiment with guinea pigs (7) is also plotted in Fig. 1. The characteristics which are apparent in these earlier series of observations are quite as apparent in the data of the present experiment. The discrepancies between the data of the two earlier series and the data of the present experiment may be due to any of a number of variable factors such as age.
and genetic constitution. It is hoped that the influence of such factors upon the geotropic orientation may be more thoroughly investigated in the near future.

In Fig. 2, where $\theta$ is plotted against $\log \sin \alpha$, the curve relating the two variables is of the type which constantly recurs in measurements of the sort that we are dealing with here. For both sets of data (i.e., with and without added load) the curves are sigmoid but with a disjunction occurring in the region of $\alpha = 35^\circ$. These observations correspond in a general sense with earlier observations on young guinea pigs (7) and adult rats (6), where the curves relating $\theta$ to $\log \sin \alpha$ were sigmoid but with the cusps appearing in the regions of $\alpha = 45^\circ$ and $\alpha = 35^\circ$ respectively.

When $\cos \theta$ is plotted against $\sin \alpha$ (Fig. 3) $\cos \theta$ decreases as $\sin \alpha$ increases, and the relation in both sets of data is apparently rectilinear with two regions in which the factor of proportionality differs.

If it is legitimate to regard the variation of $\theta$ as being determined by the conditions which determine the extent of orientation (4), a

![Graph showing the relationship between $\cos \theta$ and $\sin \alpha$.](image)

**Fig. 3.** The cosines of the angles of upward orientation $\theta$, both with and without added load are directly proportional to $\sin \alpha$. Two regions characterized by different proportionality factors are represented here.
plot of the variation of mean $\theta$ (i.e., P.E.$\theta$ with $n$ constant) against $\sin \alpha$ should display the disjunction which is characteristic of the curve relating the magnitude of response to the independent variable. Such a plot (Fig. 4) reveals a relationship which is apparently rectilinear but with a zone of discontinuity in the region of $\alpha = 35^\circ$ (3). For equal values of $\theta$, P.E.$\theta$ is practically identical under the two sets of conditions.

![Graph showing probable errors of mean $\theta$ as a function of $\sin \alpha$.](image)

FIG. 4. Probable errors of mean $\theta$ as a function of the $\sin$ of the angle of inclination $\alpha$. There were 40 observations at each slope of the inclined surface. The apparently aberrant point enclosed in parentheses was not given equal weight with the rest of the points in fitting the line.

SUMMARY

It has been found that young guinea pigs when progressing over a surface inclined at an angle $\alpha$ with the horizontal, orient upward in a way such that the path described by an oriented animal is at a mean angle $\theta$ with the base of the inclined surface. The magnitude of mean $\theta$ increases as the angle of inclination $\alpha$ increases. The function re-
lating $\theta$ and $\alpha$ is compound, being made up of two sections with a
break which corresponds to a change in the mode of progression of an
animal over the surface of the plane.

If a load of constant relative mass$^1$ is attached to the back of an
animal, midway between the fore and hind legs, testing on an inclined
surface reveals the fact that the magnitude of mean $\theta$ is increased
over the entire range of stimulation, with the two values of mean $\theta$
(i.e. with and without added load) becoming more nearly equal as
they approach 90° as a limiting value. The variation (P.E. of mean
$\theta$) is not sensibly changed by attaching a load to an orienting animal;
for equal magnitudes of $\theta$, under the two sets of test conditions, the
P.E.'s are very nearly equal.

REFERENCES


$^1$ During the time which elapsed while the experiment was in progress the
body weights of the four animals gradually increased so that it was necessary
to increase the weights of the added loads each day to keep them equal to 10
per cent of the body weights of the animals. The loads were within the ranges
which follow: Animal 1, 12.5 to 17.0 gm.; Animal 2, 11.8 to 17.0 gm.; Animal 3,
13.2 to 18.4 gm.; Animal 4, 12.0 to 17.4 gm.