The feeding regimes described reduced the body weights of the limited time and limited amount of feeding groups to 75·5 per cent and 74·5 per cent, respectively, of their initial free-feeding weights, so that these two groups were at effectively the same level of food deprivation when tested. After saline injection, there was very little difference in the intake of food and water between the two groups (Table 1). Thus there was no evidence that the rats had learned to eat more during the 2 h feeding period than would be expected from the high level of hunger.

Table 1. FOOD AND WATER CONSUMED DURING ACCESS FOR 2 H TO UNLIMITED FOOD AND WATER BY RATS PREVIOUSLY MAINTAINED ON DIFFERENT CYCLES OF FOOD DEPRIVATION

	Limited time of feeding group	Limited amount of feeding group	Satiated group
Food intake	14·1 g	13·2 g	2·6 g
Water intake	12·7 ml.	11·1 ml.	2·3 ml.

As one would expect, the satiated group ($n=7$) ate and drank significantly less ($P<0·001$, Mann–Whitney U-test) than the deprived groups. The differences between the limited amount ($n=6$) and limited time ($n=7$) groups were not significant ($P>0·2$).

Fig. 1 shows the food intake after the administration of chlorpromazine as a percentage of the intake after saline injection. The Walsh test[6] for related samples was used to test the significance of drug effects because homogeneity of variance need not be assumed. The overall pattern is clear; during the first 2 h of testing the intake of food by satiated and both types of deprived rats was depressed by chlorpromazine, but after that the intake rose and remained relatively high for 22 h. The overall food intake during the 24 h of the tests rose by about 15 per cent ($P<0·05$), so that the rises more than compensated for the initial falls. Chlorpromazine also increased the amount of food spilt. In another experiment, neither smaller nor larger doses stimulated food consumption during the period of 2 h after injection, which suggests that the time course described was not merely a consequence of changing concentrations of the drug in the tissues.

These results were unexpected: the time after injection was an important factor which determined whether chlorpromazine inhibited or stimulated food intake. Screening tests for appetite-reducing drugs are usually carried out within 2–3 h of administration, and may thus give misleading results with chlorpromazine. In patients[1], chlorpromazine usually causes a gain in weight and sometimes even obesity, and it is also used in the treatment of anorexia nervosa, but these effects may be due to water retention[7] or other factors.

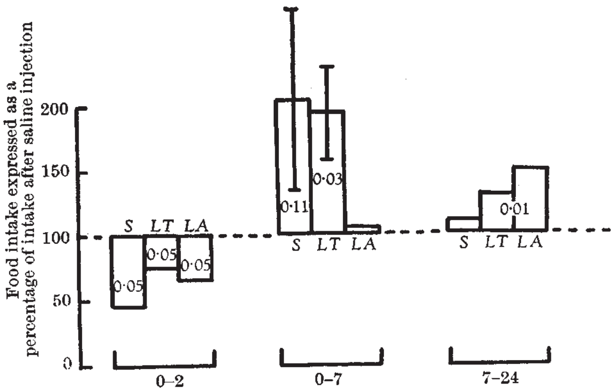

Fig. 1. Changes in food intake of three groups of rats during three consecutive time intervals after 5 mg/kg chlorpromazine. *LT*, Limited time of feeding group ($n=7$); *LA*, limited amount of feeding group ($n=6$); *S*, satiated group ($n=7$). The dashed line at 100 per cent is food intake after saline injection. The levels of statistical significance of the changes from food intake after saline are shown (Walsh test, two-tailed). Measurements of food intake began 30 min after injection. It can be seen that food intake first fell and then rose, but was also influenced by the particular feeding cycles on which the rats had been maintained for 1 week before the drug experiments began.

Surprising differences between the groups emerged 2–7 h after the start of testing. The satiated group showed very variable responses. The large standard deviation is shown in Fig. 1; according to the Walsh test the effect of the drug was not significant, although the mean rose. The rise in the limited time of feeding group was consistent and statistically significant, but there was no effect in the limited amount group. Thus appropriate deprivation of food made it easier to obtain statistically significant increases, but with only one particular type of deprivation did the drug have any effect at all. This is a case where the overt behaviour of two groups of rats with different previous experiences was not detectably different after saline injection (Table 1), but where previous experience was apparently a factor in determining responsiveness to a drug. Previous experience also modifies reactions to psychoactive drugs in other behavioural tests[8].

Water intake also depended on the time of testing after injection. At first chlorpromazine inhibited the water intake of all groups, but later the water intake rose, at about the same time as food intake rose.

Because 5 mg/kg of chlorpromazine is a fairly large dose, a general depressant action could have produced the fall in consumption of food and water which occurred soon after injection. This could hardly apply to the subsequent increases which more than compensated for the fall, despite the fact that general activity is usually found to be depressed for several hours after chlorpromazine is given. Furthermore, drugs which produce heavy sedation may at the same time stimulate eating[4].

The experiments described here therefore suggest that the food and water intakes of rats treated with chlorpromazine are mainly dependent on the time of testing after injection, but can also be influenced by previous experience of particular types of feeding cycles. Hunger induced by both limited time and limited amount feeding cycles is widely used to motivate rats used for learning experiments. Although one should be cautious in inferring effects on motivation from changes in the intake of food or water[9], the present experiments show that fluctuating levels of hunger and thirst may be expected up to at least 7 h after injection of chlorpromazine and should be considered when interpreting the results of experiments on learning in animals.

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PSYCHOLOGY

Time required for Judgements of Numerical Inequality

AN educated adult can tell which of two digits is the larger with virtually no uncertainty. By what process is this accomplished? On the one hand, it is conceivable that such judgements are made in the same way as judgements of stimuli varying along physical continua. On the other hand, numerical judgements may be made at a different, less perceptual and more cognitive, level. For instance, the task may be one of memory access, each possible pair of numerals being stored with a corresponding inequality sign; or perhaps some sort of digital computation is performed, such as counting the space between the two numerical values.

One way of exploring the nature of such processes is by examining the time which they require. Judgements of inequality for length of lines, pitch and colour are known to require longer time the smaller the difference between two stimuli[1]. Moreover, such judgements tend to show a psychophysical function—a given difference between two stimuli evokes a quicker reaction the smaller their absolute values[2]. Thus, if humans judge differences between numerals in the same way as differences along physical continua, reaction times should be inversely proportional to the difference between two numbers and smaller for smaller numbers. If, instead, the process involves direct memory look-up, there is little reason to expect such relations. Finally, if the process involves counting of the number space between the two numerals, then reaction time should be directly proportional to the difference. To explore this question, we have measured the time required for judging which of two single digit numerals is the larger.

Ten female undergraduates of Stanford University served as subjects. Each stimulus consisted of two numerals each of one digit typed 2·5 cm apart on a white background. Every non-repeating pairing of the numerals 1 to 9 was used. Each digit appeared twenty-four times on the left and twenty-four times on the right; each pair three times as $x \ldots y$ and three times as $y \ldots x$. The order was random. Subjects were instructed to throw the left-hand or right-hand of two switches according to whether the digit on the left or right was the larger. They were told to respond as quickly as possible without making errors.

The stimuli were presented through a half-silvered mirror, and were not visible until a light and timer were simultaneously activated.

Fig. 1 shows that the decision time was an approximately linear inverse function of the numerical differences between the two stimulus digits. The negative correlation is significant ($r = -0{\cdot}63$) ($P < 0{\cdot}01$). Error data (Fig. 2) show a similar trend.

We explored a number of possible equations for describing these data, and found that a reasonable fit is of the same general class as those usually found to describe discrimination reaction times for differences between physical quantities such as pitch of tone and length of line (much of the relevant literature is reviewed in ref. 3). For example, the equation $RT = K \log$ (larger/larger–smaller) which Welford[3] proposes as a general model for

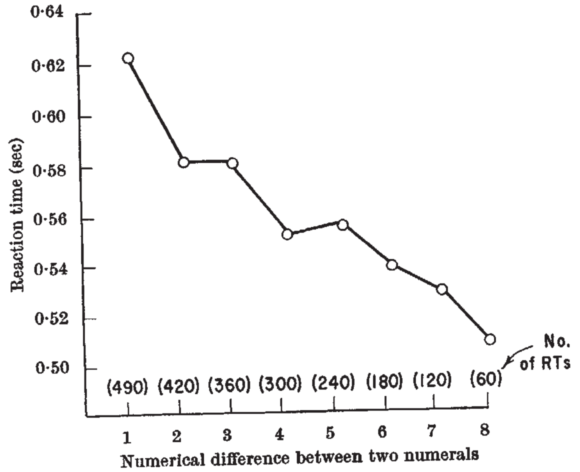

Fig. 1. Reaction time as a function of numerical difference between the two stimulus digits.

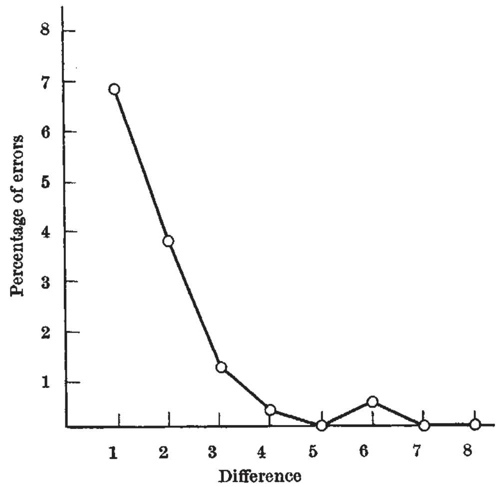

Fig. 2. Distribution of errors as a function of numerical difference between the two stimulus digits.

such situations yields a product-moment correlation coefficient of 0·75 for our data. Thus the function resembles classical psychophysical functions, in that the ratio of the two stimulus numerals is more closely related to RT than is the absolute difference between them.

These results strongly suggest that the process used in judgements of differences in magnitude between numerals is the same as, or analogous to, the process involved in judgements of inequality for physical continua.

A possible artefact in these results arises from the fact that in the set of pairs used the numerically larger digits were more often "correct" (that is, they corresponded to the proper switch) and were also more often found in pairs with larger differences. If subjects respond more quickly to single digits with higher probabilities of being "correct", this correlation among the stimulus materials would produce a spurious appearance of shorter times for pairs with larger differences. To control for this possibility, a second experiment was run in exactly the same manner as the first, except that a new set of pairs was used. For comparisons between certain pairs of this set the size of numerical differences between the two members varied while the likelihood of the component single digits being correct over the entire set was constant. For comparisons between certain other pairs the effect of probability of their members being "correct" over the entire set varied while the numerical difference between the numbers was constant. Numerical differences between pair members produced a statistically significant effect ($P < 0{\cdot}05$), while variations in probability correct did not ($P < 0{\cdot}10$). It thus seems safe to assume that numerical difference between pair members was the critical variable in the first experiment.

The decision process which these data suggest is one in which the displayed numerals are converted to analogue magnitudes, and a comparison is then made between these magnitudes in much the same way that comparisons are made between physical stimuli such as loudness or length of line.

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