liable differences appear in order 1 and 2 dendrites.

The data provide evidence for regulation of neuronal growth, at least during maturation, by "use," that is, by the degree of stimulation involved in the environmental situation in which the animal is reared. A possible explanation of the differences in synaptic size which have been reported to follow this differential rearing procedure (*7*) is that the additional synapses formed on higher-order branches may be larger than those more central in the neuron.

The failure to find such clear differences in dendritic branching in the Holloway study (*8*) may be related to several factors, such as the relatively small number of neurons examined and the particular neuronal population studied ("layer II stellate" neurons). Holloway's scoring technique—simple totals of intersections of dendrites with concentric rings—may have been insensitive to selective effects on higher-order branching, and the apparent variability in staining from animal to animal may have resulted in differences in the staining of higher-order dendrites. Finally, the longer treatment period in his study has been found to produce smaller cortical weight differences (*5, 6*).

Our results are compatible with previously reported differences in cortical depth, perikaryon size, and acetylcholinesterase activity, and suggest that the larger cell bodies may be involved in the support of the more extensive dendritic trees. It is possible that the differences in branching patterns are generated entirely or in part by some indirect effect of the environments through hormonal or general metabolic intermediates. However, most of the reported gross differences (*5*) are confined to selected brain regions; this suggests selective effects of environmental stimulation. In any case, the increased branching presumably provides increased surface for synaptic contacts, and this greater potential for interneuronal interaction suggests a greater capacity for information processing, loosely defined, in the brain of the animal reared in a more stimulating environment. One can also conceive that such processes, combined with the reported alterations in the size of individual synapses (*7*), might underlie some forms of information storage in the brain.

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References and Notes

1. F. Valverde, *Exp. Brain Res., Berlin* **3**, 337 (1967); A. Globus and A. B. Scheibel, *Exp. Neurol.* **19**, 331 (1967).
2. P. D. Coleman and A. H. Riesen, *J. Anat.* **102**, 363 (1968).
3. E. Fifkova, *J. Neurobiol.* **1**, 285 (1970); *ibid.* **2**, 91 (1970).
4. S. Schapiro and K. R. Vukovich, *Science* **167**, 292 (1970).
5. M. R. Rosenzweig, E. L. Bennett, M. C. Diamond, in *Macromolecules and Behavior*, J. Gaito, Ed. (Appleton-Century-Crofts, New York, 1971); *Sci. Amer.* **226** (No. 2), 22 (1972).
6. ———, S. Wu, R. W. Slagle, E. Saffran, *Brain Res.* **14**, 427 (1969).
7. R. W. West and W. T. Greenough, *Behav. Biol.* **7**, 279 (1972); W. T. Greenough, R. W. West, T. B. Fleischmann, paper presented at 1st annual meeting, Society for Neuroscience, Washington, D.C., October 1971; K. Møllgaard, M. C. Diamond, E. L. Bennett, M. R. Rosenzweig, B. Lindner, *Int. J. Neurosci.* **2**, 113 (1971).
8. R. L. Holloway, *Brain Res.* **2**, 393 (1966).
9. Parent stock obtained from Simonsen Laboratories, Gilroy, California.
10. E. Ramon Moliner, *Stain Technol.* **32**, 105 (1957).
11. S. Polyak, *The Vertebrate Visual System* (Univ. of Chicago Press, Chicago, 1957); W. Zeman and J. R. M. Innes, *Craigie's Neuroanatomy of the Rat* (Academic Press, New York, 1963); D. A. Sholl, *The Organization of the Cerebral Cortex* (Methuen, London, 1956).
12. Supported by NIMH grant MH 19135-01 and NSF grant GY 8744. We thank W. R. Mead for comments on the manuscript.

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Target-Set and Response-Set Interaction: Implications for Models of Human Information Processing

Abstract. *In binary character-classification tasks, reaction time generally has been reported to increase substantially with the number of target elements. However, when the targets formed a familiar set and subjects were not required to make explicit "no" responses, reaction time did not increase significantly as the target set increased in size from one to three.*

In the most commonly used paradigm for the study of character classification, subjects are presented with a single stimulus, such as a letter or a digit, and must indicate whether or not it matches any of the stimuli contained in a previously memorized target set. Typically, results obtained with this experimental task indicate that the time taken to determine that a stimulus is indeed a member of the target set increases linearly with the size of the target set, at a rate of about 35 msec for each additional character. This result has been taken to mean that the characters in the target set are represented individually in memory, and that these memorial representations are searched serially at about 30 characters per second to determine if a match exists (*1*).

The target sets used in character classification experiments usually vary randomly in composition from trial to trial. Even when the same set is used for a block of trials, however, there is seldom any logical connection among the characters in the set. Thus, it is possible that the conclusions drawn about the process of character classification are limited to situations in which subjects may have difficulty dealing with a set of characters that are unfamiliar as a set (*2*). The initial pur-

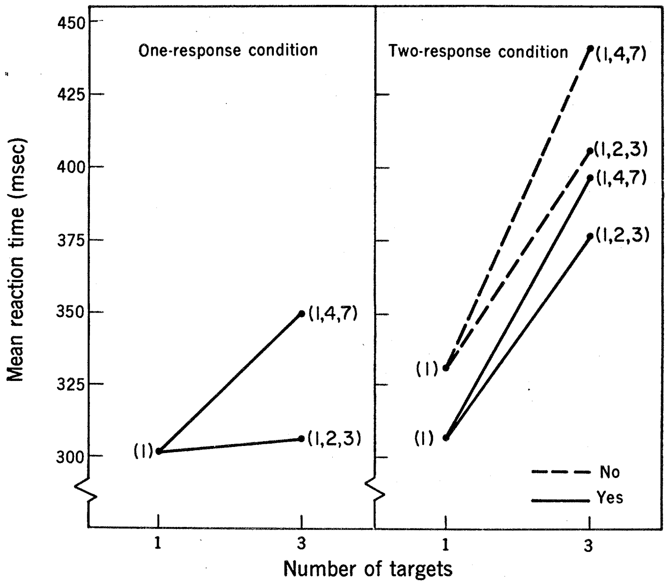

Fig. 1. Mean reaction time as a function of number of target elements for one- and two-response tasks. The numbers in parentheses represent the target set used at each point.

pose of the present research was to compare processing when the size of the target set was increased in either a "natural" or an "unnatural" fashion. To this end, a baseline condition was defined in which the target set consisted of the single digit 1. A natural extension to set size three consisted of the digits 1, 2, and 3, while an unnatural extension to set size three consisted of the digits 1, 4, and 7. In all of these conditions, the nontarget set was simply the complement of the target set (*3*).

So that the task would be as easy as possible, each subject served in only one experimental condition. Moreover, each subject was instructed to indicate that the presented stimulus was in the target set by depressing a key with the index finger of his right hand. He was not to respond at all if a nontarget was shown.

The stimuli were 30-point copperplate Gothic numerals presented for 150 msec at a viewing distance of 84 cm in a two-channel tachistoscope. Reaction time (RT) was measured from the onset of the stimulus to the depression of the response key. Following the description of the task there were 144 test trials, on half of which the stimulus was a randomly selected target and on the other half a randomly selected nontarget. Six subjects were assigned at random to each of the three test conditions.

The results are shown in the left panel of Fig. 1. For the unnatural condition there was a 48-msec difference in mean RT between set size one and set size three ($t_{(10)} = 4.55$, $P < .01$), but in the natural condition there was an insignificant difference of only 4 msec. These differences may be translated into slopes of 24 msec per character and 2 msec per character, respectively.

At this point we discovered that Marcel (*4*) had obtained data under conditions very similar to our natural condition, but with totally different results. As successive elements (1; 1, 2; 1, 2, 3, 4) were added to the target set, the mean RT increased by about 26 msec per character, which is similar to the rate found in previous research (*1*) with unrelated elements and also above in our unnatural condition. Marcel's study differed from ours in several details, one of them being that he required his subjects to make an explicit "no" response to nontargets. Although Marcel had measured RT's for vocal reactions, we attempted to study the difference between one- and two-response tasks in the context of our key-pressing paradigm. Three additional groups of four subjects each were used in the conditions described earlier, but now each subject was instructed to indicate that a stimulus was in the target set by depressing a key with the index finger of his right hand, and to indicate that it was a nontarget by depressing another key with the index finger of his left hand.

The results for the two-response conditions appear in the right panel of Fig. 1. For the natural conditions, with two responses, the difference in "yes" RT between set sizes one and three was 70 msec ($t_{(6)} = 9.14$, $P < .001$). Thus, simply requiring an explicit "no" response increased the slope for "yes" RT's under natural conditions from 2 to 35 msec per character. The slope in the unnatural condition was also increased, from 24 to 45 msec per character, by the addition of an explicit "no" response (*5*). The error rate did not exceed 1.5 percent in any experimental condition.

Mean RT was analyzed for each digit individually in the two natural conditions. For "yes" responses there were no systematic differences among the digits 1, 2, and 3. Moreover, "no" RT did not decrease systematically as a function of the remoteness of a digit from the end of the target set (*6*). This suggests that digits were not represented in analog fashion in memory.

There are several ways to interpret these findings. We might conclude that parallel processing, as indicated by the virtual invariance of RT with set size, can occur only when the elements in the target set are related in a well-learned way and when the response is a simple one. Serial processing, as indicated by sharply increasing RT as a function of set size, may occur when the target elements are unrelated or when the response is relatively difficult. However, it is also possible to conclude that processing of the elements in memory was parallel throughout, with differences in slopes reflecting differences in processing capacity available for character classification under the various experimental conditions (*7*). For example, if it was more difficult to remember the stimulus-response assignment in the two-response task than in the one-response task, and if some processing capacity was required to retain the association, then less capacity would have been available for character classification, which may consequently have been slowed (*8*). Similarly, the greater slope for the unnatural conditions might represent some diversion of processing capacity from character classification to the task of holding the set in memory.

Apart from the theoretical distinction between parallel and serial processing, our results have a methodological implication. Around the turn of the century, Donders' subtractive analysis of reaction time was criticized by Külpe (*9*) and Lange (*10*), among others. The essence of their argument, in modern terms, was that later stages in information processing (such as response selection) could affect the processing carried out during earlier, supposedly independent stages (such as stimulus discrimination). The lack of independence of stages in the present experiment supports this critical view and serves as a reminder that subtractive reaction experiments must be interpreted with care.

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References and Notes

1. S. Sternberg, *Science* **153**, 652 (1966).
2. → P. M. Fitts and G. Switzer, *J. Exp. Psychol.* **63**, 321 (1962).
3. We are not prepared to fully define the terms "natural" and "unnatural" at this time. In the case we have selected for investigation "familiarity as a set" is confounded with successiveness. Dissociation of these variables deserves further effort.
4. A. J. Marcel, *Acta Psychol.* **33**, 77 (1970).
5. Related work on response assignments has been reported by B. Forrin, M. L. Kumler, and R. E. Morin [*Can. J. Psychol.* **20**, 115 (1966)] and by B. Forrin and R. E. Morin [*J. Exp. Psychol.* **71**, 40 (1966)].
6. The absence of a remoteness effect in the present experiment may be contrasted with the observation of such effects → D. V. DeRosa and R. E. Morin [*J. Exp. Psychol.* **83**, 472 (1970)]. One possible source of the difference is that their subjects were tested on a variety of target sets.
7. D. W. J. Corcoran, *Pattern Recognition* (Penguin, Baltimore, 1971); J. T. Townsend, *Percept. Psychophys.* **10**, 161 (1971).
8. Note, however, that for set size one, mean "yes" RT's did not differ significantly for the one- and two-response tasks (302 and 307 msec, respectively). Capacity considerations would suggest that the two-response task should have been slowed, even for set size one. Unfortunately, it is not possible to predict the magnitude of the slowing expected on this loose verbal model. It is interesting to speculate about why it may have been more difficult to remember to respond to nontargets by pressing a key with the left hand than to remember not to respond at all. One possibility is that subjects may have attempted to explicitly associate nontargets with the "no" response in the former case, but made "no" responses by default in the latter case.
9. O. Külpe, *Outlines of Psychology* (Macmillan, New York, 1895).
10. L. Lange, *Philos. Stud.* **4**, 479 (1888).
11. This research was supported by a contract between the Engineering Psychology Programs, Office of Naval Research, and the Johns Hopkins University.

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