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Cortical–Cortical Pathways involved in Reinforcement

To learn a simple pattern discrimination an organism must be able to integrate its response experience with reinforcement information. The importance of cortical pathways in this integration can be tested with people who have had midline section of the corpus callosum and anterior commissure in an effort to control the inter-hemispheric spread of seizures[1].

One woman was tested who had undergone surgery 5 yr before this study was made. She had recovered quickly from the operation and now, to a casual observer, her behaviour appears entirely normal. She sat before a panel containing two small displays, each placed horizontally and equidistant from a fixation point. On the right display, the word "right" or "wrong" appeared. The left display contained two nixie (neon light) tubes, one above the other, and through either tube the signals (0) or (1) could be presented. Immediately to the left of each tube was a response button.

Two stimulus conditions of short duration (100 ms) were presented to the woman in random order. Two vertically placed nixie tubes were briefly illuminated to display either (1) above and (0) below or (0) above and (1) below. By pushing either of the two response buttons the display on the right would immediately light up for an equally short period indicating whether the response was "right" or "wrong". Pressing the button associated with the tube indicating (1) yielded a flash of the word "right" and conversely the button next to the tube indicating (0) produced the word "wrong". The experimenter could reverse this condition enabling (0) to be associated with "right" and (1) with "wrong".

The woman was told to place the left index finger midway between the two response buttons. Immediately after the nixie tubes were illuminated, the top or bottom button was pressed. Each trial began with the experimenter asking the subject to fixate the point in the midline. In this condition, the display producing the answers or reinforcement fell into the visual field of the left hemisphere. At the same time the stimulus display in the left visual field was seen exclusively by the right hemisphere. A trial ended by telling the woman whether the response was "right" or "wrong".

In the initial test the (1) against (0) discrimination was projected to the right hemisphere and the reward signal for response to the (1) was flashed to the left. After thirty-five trials the woman responded at only a chance level.

A second condition was introduced in which she was asked to fixate a point to the left of the discrimination display. This allowed both the discrimination and the reward signal to be seen in the visual field of the left hemisphere. On the fourth trial she began a series of ten correct responses.

In a third test, she was again instructed to fixate the point midway between the displays, thus dividing the reinforcement and discrimination information between the two hemispheres. The conditions were reversed so that a response to (0) was now correct. On this first trial, the woman was admonished by the experimenter for responding in error to so easy a problem. On the subsequent trials, she herself would sigh and bemoan an error. In this condition, she began a series of ten correct responses on the fifth trial. After her series of correct responses, she was asked to report why she responded as she did. She said simply that she responded when the lights came on. When pressed to explain how she made her choices, she said she would hit the button next to the (1). In fact, she had been responding to the (0) signal. Two normal people were run in all of the foregoing tests. In both cases they learned all tests with ease in three or four trials.

No learning was evident in the brain-bisected subject in the first condition in which the discriminative cues (1 and 0) were presented to the right hemisphere and the reinforcement information was presented to the left hemisphere. This result raises questions on the part the subcortex plays in mediating reinforcement information, and emphasizes the need for cortical–cortical integration in the reinforcement process for this type of test. Clearly, the task was insoluble to a subject having no cortical connexions between the reinforcement information and the discriminative cues. Simply presenting the brain with a reinforcement following a correct response was not a sufficient condition for learning.

In the second condition, the woman learned the task quickly. With all the information entering the left hemisphere, the performance of the "split-brain" was comparable with a normal person's performance in the first condition.

In the third condition, the discriminative cues were available only to the right hemisphere but the reinforcement information was in effect presented to both hemispheres. This is caused by the existence of a cross cueing mechanism[2,3]. During the first few trials of the third condition, the woman through general bodily responses expressed her dissatisfaction at being incorrect. The utterances and somatic responses triggered by the left hemisphere are read off and interpreted by the right hemisphere as an error in its performance. In these conditions, the task was readily learned. Comparing this result with the outcome in the first condition indicates that the right hemisphere is capable of learning the task if it is presented with both the discriminative stimulus information and the reinforcement information. While the right hemisphere has little or no ability for verbal expression[4], its ability to learn this task agrees with findings which indicate that the right hemisphere can recognize simple vocabulary and understand basic logical relations[5,6]. When the woman was asked to report what was learned in this third condition, it emerged from the incorrect verbal report of the left hemisphere that only the right hemisphere had learned the task.

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J. D. JOHNSON
M. S. GAZZANIGA

Department of Psychology,
University of California,
Santa Barbara, California.

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