Pergamon

PII: S0028–3932(98)00056–6

Neuropsychologia, Vol. 36, No. 10, pp. 1025–1032, 1998

0028–3932/98 $19.00+0.00

Hemispheric differences in serial reversal learning: a study with commissurotomy patients

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(*Received* 11 *December* 1997; *accepted* 9 *February* 1998)

Abstract—A serial reversal learning task involving tactile-proprioceptive discrimination and manual responses was presented alternately to the left and the right hemisphere of four "split-brain" patients. In each trial, one of two rods that differed in both diameter and surface texture was placed in the patient's hand out of view. The patient was trained to match it to samples according to either size or texture and non-verbal audio–visual feedback was used to signal the correctness of each response. After reaching five consecutively correct responses, the feature to be matched was switched. When the patient again made five consecutively correct responses, the feature to be matched was reversed back. This procedure was repeated until the end of a 200-trial training run. The two hemispheres learned equally readily on the first learning task. The right hemisphere had much greater difficulty in learning the reversals than the left hemisphere and this was not attributable to a strong tendency to stay with a previously correct match. Learning with the left hemisphere showed relatively stable performance across successive reversals, whereas that with the right hemisphere showed high lability. Control trials showed that the hemispheres were equally competent in making the basic tactile-proprioceptive discriminations. Comparisons with the findings on (a) three control patients and (b) training with unrestricted visual input showed that learning with two hemispheres was easier than learning with either one alone; performance regulated by both hemispheres was also more stable. © 1998 Elsevier Science Ltd. All rights reserved

Key Words: split-brain; left hemisphere; right hemisphere; manual; tactile; serial reversal learning.

Preface

The study reported here was conducted at Dr Roger W. Sperry's laboratory during my sabbatical leave from the University of Southern California in 1979–80. Data analysis and graphic presentation of the results were finished soon after the end of the sabbatical leave and I was impressed by the robustness of the findings. Regretfully, the more immediate demands of my regular job delayed the writing of the article. When I apologized to Dr Sperry several months later, he said: "Suit yourself; certainly no problem here". Then, time just flew... In 1994, I presented this work at a special program in honor of Dr Sperry at the annual convention of the American Psychological Association. After my presentation, several friends who are still in the field told me that I should write it up. I feel privileged to have this article included in this special issue honoring Dr Sperry in whose laboratory I spent several exciting and enjoyable years as a postdoctoral fellow. During those golden years, I had the freedom to choose my study topic yet was not required to apply for grant funding; the laboratory had its own machine shop; there were funds to provide assistant help; perhaps most importantly, Dr Sperry did not seem to think that good work necessarily requires long hours spent in the laboratory. These circumstances encouraged me to start simultaneously a career and a family for which I am ever thankful.

Introduction

Most studies on the functional asymmetry between the two cerebral hemispheres have employed a testing approach commonly practiced in the assessment of human abilities: Each response is recorded and scored, but there is no immediate feedback about its correctness to the subject. Although much has been learned about the propensities and abilities of each hemisphere (e.g. see [11, 15, 16] for general reviews), this testing approach has yielded little direct information on how the two hemispheres might differ in their ability to correct errors when

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given feedback. The readiness with which behavior can be modified to suit changing conditions is important for adaptation and survival and this learning ability has often been used to distinguish different animal species along the phylogenetic scale.

In the present study, a training procedure commonly used in non-human animal studies was employed to compare (a) the learning abilities of the left and the right hemisphere and (b) learning with either hemisphere alone vs learning with both hemispheres. A two-choice learning task was presented, followed by a series of reversal training. Comparisons were made on the abilities to learn (a) the initial task and (b) the serial reversals.

Methods

Subjects

The subjects were seven right-handed commissurotomy patients of Drs J. E. Bogen and P. J. Vogel. The patients received either full or partial surgical disconnection of the two cerebral hemispheres in order to alleviate intractable epileptic seizures. Five "full commissurotomy" patients had presumed complete bisection of the corpus callosum and the anterior and the hippocampal commissures. Two "partial commissurotomy" patients differed from the first group in that the posterior one third of their corpus callosum was left intact and they did not show the split-brain syndrome [4]. For the present study the partial commissurotomy patients served as "control" subjects. A brief summary of the subjects is presented in Table 1. Additional details about them have been reported elsewhere [4, 9].

Study design

All seven subjects participated in the first two training sessions. Six of them also took part in a third session. (One could not participate because of illness.) The first two sessions were scheduled one or two weeks apart, the third one followed approximately five months later. For each session, four training runs of 200 trials each were conducted for the main task of serial reversal learning. A short rest was given after the first and the third run and a longer break was given after the second run. The task involved tactile-proprioceptive input to the hand and manual responses. The order of hand use was L, R, L, R for the first session and R, L, R, L for the second and the third sessions.

In each of the first two sessions, all four training runs were conducted behind an opaque shield to exclude visual information. Manual stimulation and responses are associated primarily with the contralateral hemisphere. Therefore for "split brain" subjects learning with the use of a hand can be assumed to indicate learning with its contralateral hemisphere. In the third session, the first two training runs were conducted while allowing the subjects full view of the stimulus objects and the manual responses and the second two training runs were conducted without visual input. Free visual input allows both hemispheres to participate in the learning task regardless of the hand used. Thus the purpose of the third session was to obtain within-subject comparisons between learning with both hemispheres and learning with either the left or the right hemisphere alone.

For all three sessions, two types of control trials were administered, both at the beginning and at the end of a session. One type was to ensure that the two hands were equally competent in making the basic tactile-proprioceptive discriminations, the other was to check if the tactile-proprioceptive input was transmitted only to the contralateral cerebral hemisphere of the five full commissurotomy patients. All control trials were presented behind an opaque shield to exclude visual information.

Table 1. Subject characteristics

Name	Sex	Age in years at: Onset of seizures	Surgery	Testing
Full commissurotomy patients				
AA	M	5	13	28
LB	M	4	13	27
NG	F	18	30	47
NW	F	3	36	50
RY	M	17	43	57
Partial commissurotomy patients				
DM	M	11	23	35
NF	F	14	26	37

Apparatus

An opaque shield was placed on the training and testing table to provide a visual barrier between the subject and the experimenter. The use of the shield also enabled training and testing out of the subject's view. In addition, audio–visual feedback about the correctness of a response was delivered from the vertical midline of the shield. The shield was 30″ in width and 13″ in height and it was supported by flaps hinged to its two sides. The lower edge of the shield was 6″ above the tabletop. The gap was covered by two layers of dense black nylon fringe that provided a visual barrier but could allow the subject's hand(s) to extend through. A sketch of a similar shield can be found elsewhere [10]. On the front side of the shield facing the subject, a $3.5 \times 6''$ loudspeaker was mounted midway along its top edge and the tips of a red and a green diode were shown through two 0.25″ holes drilled along the vertical midline, respectively 5″ and 3″ from the bottom edge. On the back side of the shield facing the experimenter, the loudspeaker and the diodes were wired to a small control box placed on the table out of the subject's view. A toggle switch on the control box could be flipped by the experimenter to deliver a 1 s signal on the correctness of a subject's response. A correct response was indicated by a pleasant tone (generated by sinusoidal waves) and the lighting of the green diode. An incorrect response was indicated by an unpleasant tone (generated by square waves) and the lighting of the red diode. The tones were delivered from the loudspeaker. At the start of the study, each subject was asked to judge the relative pleasantness of the two tones and all seven of them agreed with the experimenter in the choice of the more pleasant one. At the beginning of each training session, all subjects were told to associate the lights with traffic lights, with red meaning "stop" or "no" and green meaning "go ahead" or "OK".

The main task of serial reversal learning involved the use of two "sample" rods and two "match" rods made of Plexiglass. The two sample rods, each 5″ in height, were mounted standing 8″ apart from center to center on a base board. They differed in both circumference and surface texture. The "big-smooth" one had a diameter of 1.25″ and a smooth surface, the "small-