That transplanted cerebral tissue maintains a high-performance metabolic state for hours after vascular transfer (Table 1) is evidenced by the propensity of brain to protect its intrinsic cellular integrity as it extracts large quantities of oxygen and glucose during periods of reduced cerebral perfusion. Measurements of blood lactates across brain revealed no significant differences between arterial and venous samples. This supports recent work (*6*) suggesting that normal brain does not contribute lactate to cerebral venous blood.

A review of the cerebral blood flows in the homotransplant of the canine brain suggests that previously published values (*7*) for such flow in this species are too high. Certainly our figures for the dog are more in accord with those of McClure and Green (*8*).

Review of histological sections of brain tissue transplanted up to 2 days has failed to reveal any cellular abnormalities (in type or density) which would be compatible with rejection phenomena. Superficial necrosis of the temporal lobes in two brains was probably related to the surgery.

While the present design of the experiment utilizes anticoagulation, the interposition of the canine brain between the carotid–jugular circulation of the recipient "normalizes" the performance of the homotransplant as indicated by the factors reported in this study. Further increase in the longevity of the transplanted, isolated brain and use of the implantable monitoring system should provide unusual opportunities for further brain research.

Our experiments demonstrate for the first time the feasibility of transplanting the canine brain, for protracted periods of time, as an isolated organ into the cervical circulatory environment of a recipient while being able at the same time to monitor continuously its electrical, metabolic, and physiological state.

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Efficiency of the Conditioned Eyelid Response

Abstract. *A method for estimating directly the efficiency of the conditioned eyelid response is capable of reflecting marked changes in response efficiency during acquisition of the conditioned response.*

It has been widely assumed that the conditioned eyelid response performs some adaptive function (*1*, *2*). Anticipatory closure of eyelids in response to some conditioned signal may be supposed to afford protection in some degree from the noxious air puff which follows. Nevertheless, this assumption has received scant support from experiments.

Indirect evidence for the adaptive nature of the conditioned eyelid response has chiefly been drawn from measurements of response amplitude and latency. With regard to the first of these it was early shown that the *amplitude* of responding increases during acquisition trials (*3*, *4*), and this has since been confirmed (*1*). It is evident, however, that this increase is not in itself an indication of adaptive change unless the *timing* of the conditioned blink is appropriate to the arrival of the air puff.

It is in this latter aspect that results are conflicting. The most widely quoted recent study (*5*) showed a slight but significant *increase* in response latency (evidenced as a shift in median latency toward the onset of the air puff) during the last 30 trials of a series of 150 trials. Conversely, a *decrease* in latency has been reported over extended training periods (*6*).

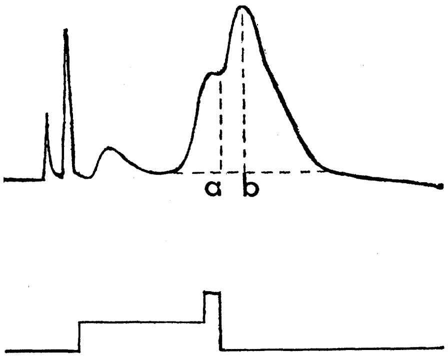

Fig. 1. How the ratio score is measured: *a*, amplitude of CR at point of UCR onset; *b*, maximum UCR amplitude. The ratio is *a*/*b*. The event marker at the bottom shows onset of CS and UCS; the stimuli terminate together.

Campbell and Hilgard also found a decrease in response latency during 50 acquisition trials (*7*). They noted that subjects who could be conditioned most readily had the lowest average response latency. Spence has demonstrated this relationship more precisely by separating acquisition curves for good and poor conditioners, showing that the former decrease while the latter increase in latency over a series of 100 trials (*1*).

While these examples could be multiplied, they suffice to illustrate the contradictory results which arise from the measurement of latency. One possible explanation may lie in the variability of latency, and this is reflected in the fact that it is the least reliable of the standard measures of conditioning—frequency, amplitude, trials to criterion, and latency (*7*, *8*).

In our study, adaptive behavior was assessed by estimating the efficiency with which the conditioned response (CR) enabled the subject to avoid the puff of air; assessment involved selection of an appropriate target latency at which to measure amplitude. Such a target can be functionally defined by measuring the amplitude of the anticipatory CR at the point at which the blink, that is, the unconditioned response, occurs, expressed as a proportion of the amplitude of the reflex blink (see Fig. 1).

We suggest that a convenient definition of the efficacy of the conditioned response is the extent to which it avoids the unconditioned stimulus (UCS) and contributes to or obviates the necessity of the unconditioned response (UCR). Thus a "perfect" CR is

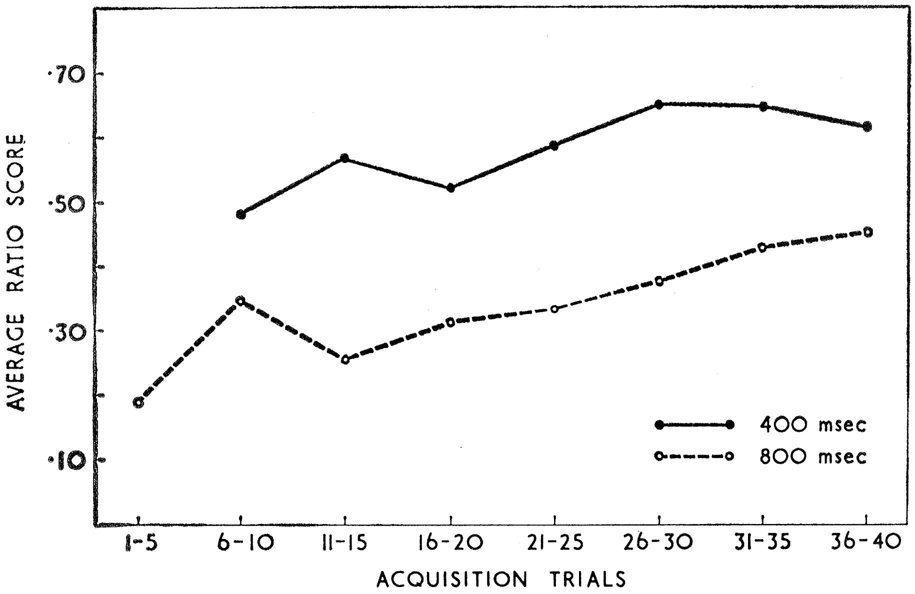

Fig. 2. Average ratio scores of 400- and 800-msec CS–UCS interval conditioning groups, showing the superiority of the shorter interval. This figure also illustrates the general increase of the ratio over successive trials (*11*).

one which completely avoids the UCS, making the UCR unnecessary.

To examine the properties of the measure just described, 48 adult male volunteers without previous experience of any pyschological studies were conditioned for 48 trials by the procedures routinely used in our laboratory (*9*). The conditioned stimulus (CS) was a tone of 1000 cy/sec at 65 db, overlapping an air puff of 60-msec duration. In order to study the adaptive behavior of the eyelid response on a reasonably general basis, subjects were assigned randomly to the cells of a 2 by 2 by 2 factorial design representing puff intensities of 3 or 6 lb/in^2. (1.2 or 1.4 atm), interstimulus intervals of either 400 or 800 msec, and continuous as opposed to partial (two-third) reinforcement. A CR was scored as any departure of 1 mm or more from the stable base line, and the ratio of each response was scored as the amplitude of the CR at the point of departure of the slope of the UCR, over the peak amplitude of the UCR. Where the CR failed to overlap, or completely overlapped the UCR (6 percent of CR's) the value of the ratio is, of course, either 0.00 or 1.00, respectively. The average numbers of CR's on which these ratios were based were 20.7 (400-msec group) and 21.5 (800-msec group).

The distribution of the ratio scores was sufficiently normal that transformations were not considered necessary for statistical analysis. It should be noted that these ratio scores are based only on trials on which a CR occurs and, therefore, avoid the cumulation of zero scores. The split-half reliability of the measure was .89; this value compares very favorably with published estimates (*4*, *10*) of the reliability of more conventional measures (for example, frequency, .86; amplitude, .88; latency, .60). In order to assess the overall change in the ratio measure during acquisition, groups were combined in an analysis of variance of the main effects for subjects and for trials in blocks of six. The analysis revealed a significant increase over trials (F 46,207 $= 5.15$, $P < .005$).

A factorial analysis was next performed on the average of the first five and last five responses of each subject. The mean score for the first five trials was .401; for the last five it was .521. The difference is significant (F 1,68 $= 6.58$, $P < .025$). Thus a measurable increase in the efficiency of the anticipatory response was demonstrated independent of CR frequency.

Rather surprisingly, puff intensity failed to show any relationship with response efficiency as measured by the ratio. The CS duration, however, yielded a highly significant difference, the means for the 400- and 800-msec intervals being .580 and .343, respectively (F 1,68 $= 25.47$, $P < .001$) (see Fig. 2).

This difference presumably reflects the greater difficulty of appropriately timing the CR at the longer interval. It is of interest that neither puff intensity nor interstimulus interval produced differences in the *absolute number* of CR's. Hence the ratio score is more sensitive to experimental manipulations than a simple count of CR's.

Median *latencies* were compared for blocks of 12 trials, and for first and

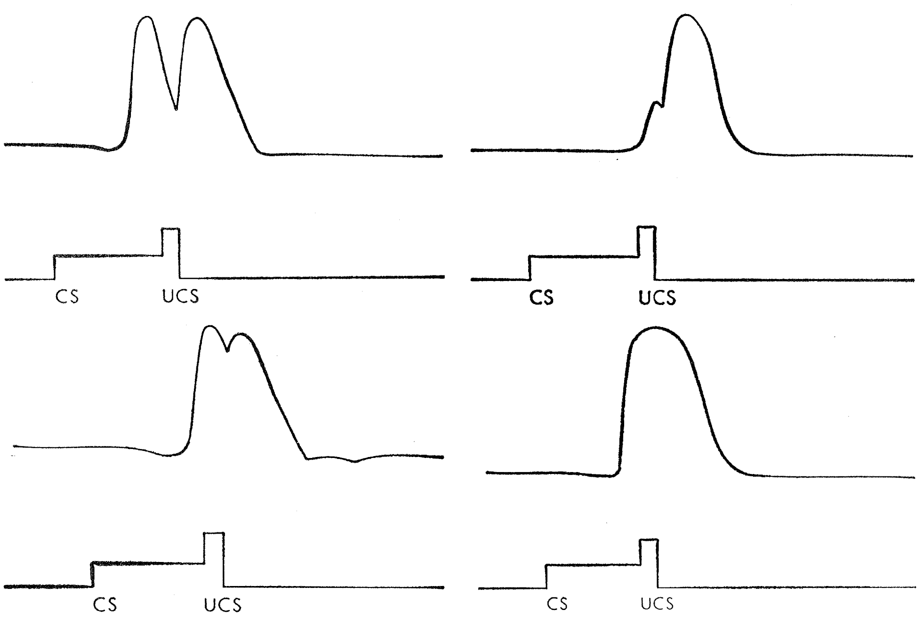

Fig. 3. Actual records selected to illustrate four phases of CR development: (top left) inefficiently timed high-amplitude response; (top right), appropriately timed-low-amplitude response; (bottom left) appropriately timed high-amplitude response; (bottom right) maximally efficient response. The event marker at the base of each figure shows CS and overlapping UCS onset and duration.

last halves of the acquisition series, but these failed to show any significant shift of latency. There was a nonsignificant overall tendency for latency to decrease from first to last half, but these scores were found to be extremely variable.

Figure 3 shows examples of actual responses selected from various stages of CR development. The responses range from a relatively ineffectual response in terms of puff avoidance (Fig. 3, top left) to complete avoidance of the puff and absence of UCR (Fig. 3, bottom right).

These responses also illustrate an aspect of the latency data which became apparent in examining the records, namely that the latency function fails to reflect the adaptive change for the reason that responses may differ in amplitude or form in such a way as to offset the effect of any increase or decrease in latency. Indeed, a given response may be appropriately placed, in relation to the UCS, either by increasing or decreasing its latency, depending upon its amplitude and rise time. Thus a complex interaction between time and amplitude seems required for efficient adaptive responses. The exact mechanisms underlying increasing efficiency presumably depend on feedback concerning latency, form, and amplitude from previous responses.

Several further characteristics of the ratio score are of interest. Appreciable variation in the pattern of CR development was reflected in these scores. As an alternative estimate of the change across trials, slopes representing the linear component of regression upon trial number were computed for each subject individually. Of these, 38 were positive, indicating that increased efficiency was the modal pattern. These slopes ranged from .0048 to .0824, of which 15 were significant at the .01-percent level or better. It should be noted that these slopes were used as an approximate estimate of individual performance, but that many individuals showed nonlinear patterns. Among these was an appreciable number who appeared to achieve, and then to lose, the effective response, although as shown by the analysis reported above the overall trend was toward successively better response levels.

The failure of CR *frequency* to reflect the effects of CS-UCS interval, whereas the ratio was highly successful in this respect, carries the implication that the two measures are not closely related, and this was in fact the case. The correlation between average ratio and number of CR's was .205 (not significant); thus the measures are virtually independent.

The data further show that the behavior of the ratio measure is not simply accounted for in terms of amplitude or magnitude measures of the CR; nor is it due to decreases in UCR amplitude.

Our measure of conditioned response efficiency is capable of reflecting adaptive changes in the eyelid CR which are obscured in the conventional measures traditionally in use. It is useful to regard the conditioned response as performing a part of the work of the reflex on which it is based; the proposed measure may be designated as the "work ratio" of the conditioned response.

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9. I. Martin, *Behav. Res. Therap.* **1**, 255 (1963). The essential features of the procedure are the use of a photoelectric pick-up which avoids mechanical interference with the eyelid, and masking of the conditioning sequence within a simple vigilance task.
10. The calculation of the split-half reliability followed the procedure Hilgard and Campbell (*4*) in order to afford a comparison with the very few published estimates of reliability. Average scores for the first and last quarter were compared with the middle half; no correction for attenuation was employed. The value reported is that for continuous reinforcement, the condition obtaining in the earlier report.
11. Only reinforced trials are included in these curves, since, for the partial reinforcement condition, the ratio score does not apply to trials on which the UCS was omitted. The first trial block is based on the scores of seven subjects, there being no responses recorded in this block for the 400-msec interval. From trial block 2 onward, the number of subjects responding increased from 21 to 46, divided fairly evenly between the two groups.
12. The financial support of the Medical Research Council and the encouragement of H. J. Eysenck are gratefully acknowledged.

16 July 1965

Convection Plumes and Insects

In "Convection plumes from *Ulmus americana* L." [*Science* **148**, 392 (1965)] Peterson and Damman make a good case for the opinion that the observed plumes were convection columns (attended by condensation) above treetops.

My wife and I observed the same phenomenon on 20 June 1964 while driving on the Capitol Beltway up the Maryland slope of the Potomac from the Woodrow Wilson Bridge. The time was just after sunset, the terrain below a swampy flood-plain, the sky was clear, and the visible columns, which extended for 2 or 3 meters above each treetop, wavered slightly from side to side in the still air. The occurrence was so striking—the first I had observed in 40 years as a weather observer and meteorologist—that we mentioned it to friends who lived nearby. They assured us that the columns were swarms of insects or gnats which collected above the treetops during summer evenings and became visible just after sunset against the bright northwest sky.

On further examination I concluded that this was the obvious explanation. The columns were too dark and wavered too much to be moisture columns. Insects were not present at ground level because (like fireflies) they had all congregated in the warmer air at treetop level, where, perhaps, the convective columns bore them up.

Damman and Peterson's statement that "there were no local concentrations of smoke or insects in the air that could have contributed to the phenomenon" is therefore subject to question, especially in view of the season and topography, even though their meteorological data and the explanation of the convective columns may be valid. The fact that the columns contain condensed water vapor from transpiration should also be verified before the phenomenon (as explained) is considered to be an established fact. Even though rare, such conditions must be frequent enough to permit further verification under similar conditions next summer.

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