

# CANADIAN THESES ON MICROFICHE

I.S.B.N.

# THESES CANADIENNES SUR MICROFICHE



National Library of Canada  
Collections Development Branch

Canadian Theses on  
Microfiche Service

Ottawa, Canada  
K1A 0N4

Bibliothèque nationale du Canada  
Direction du développement des collections

Service des thèses canadiennes  
sur microfiche

## NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

THIS DISSERTATION  
HAS BEEN MICROFILMED  
EXACTLY AS RECEIVED

## AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

LA THÈSE A ÉTÉ  
MICROFILMÉE TELLE QUE  
NOUS L'AVONS REÇUE

EVENT-RELATED POTENTIALS ASSOCIATED WITH  
FEEDBACK IN A CONCEPT FORMATION TASK

Michelle Delisle

Thesis submitted to the School of Graduate  
Studies and Research of the University of  
Ottawa for the degree of Master of Arts in  
Psychology.

University of Ottawa

May 1982



M. Delisle, Ottawa, Canada, 1982



UNIVERSITÉ D'OTTAWA  
UNIVERSITY OF OTTAWA

## ACKNOWLEDGEMENTS

This dissertation was prepared under the supervision of Assistant Professor Donald T. Stuss, Ph.D., of the School of Psychology and Faculty of Medicine of the University of Ottawa. The author wishes to express sincere thanks to Dr. Stuss for his support and his enormous patience and availability.

The author is also thankful to Ms. Edna Leech and Dr. T. W. Picton for their assistance in the elaboration of the project. The author is also much indebted to Francine Sarazin who introduced her patiently to the laboratory and to Gilles Hamel for his help in the technical set-up. Thanks to Theresa Drapeau for her help during the running of the subjects, and to Ms. Diane Brazeau for the preparation of the manuscript.

This dissertation was completed while the author was receiving a bursary from the "Ministère de l'Éducation du Québec".

## ABSTRACT

Using a paradigm designed to control for cognitive strategy, probability and confidence level, event-related potentials obtained to feedback stimuli (FB) in a learning situation were compared to those obtained in a guessing situation. Subjects were presented with series of two trials. On each trial, two visual stimuli were presented, each containing two criteria. In the experimental condition, subjects had to use FB information provided on each trial to cancel irrelevant dimensions in order to learn the correct criterion within the two trials of each series. In the control condition, subjects had to guess on each trial which one of the two stimuli contained the correct criterion, and to remember the nature of FB given on both trials of each series. A greater post FB frontal negativity (350-550 latency range), only significant for negative feedback trials, was found for the experimental group compared to the control group. For both groups, a significantly greater post FB positivity was found on the second trial than on the first one, and this, whether FB was positive or negative. It was suggested that the frontal negativity could reflect selection and monitoring processes involved in the cancellation of dimensions, while the greater positivity could be associated with the greater memory load implied for both groups following second FB presentation.

## INTRODUCTION

Event-related potentials (ERPs) have proven to be useful tools in the study of electrophysiological manifestations of cognitive processes (Donchin, Ritter, & McCallum, 1978; Picton, Campbell, Baribeau-Braun, & Proulx, 1978). Their value has been dependent upon the ability of a paradigm to focus on specific aspects of the cognitive processes under study (Picton & Stuss, 1980). One promising avenue of research is the study of ERPs associated with feedback information processing. Evidence exists that the processes involved in hypothesis testing could be reflected in specific ERP components in a general yet systematic manner (Donchin et al., 1978).

Feedback (FB) may be defined in different ways. Some have considered feedback as any stimulus that confirms or disconfirms a decision (Friedman, Hakerem, Sutton, & Fleiss, 1973; Sutton, Braren, & Zubin, 1965). Donchin et al. (1978) have suggested that a stimulus containing data about prior performance must imply the use of information to alter future performance in order to be considered feedback. To date, ERP studies dealing with feedback paradigms have used guessing tasks (Donchin, Kubovy, Kutas, Johnson, & Herning, 1973; Friedman et al., 1973; Ruchkin, Sutton, & Tueting, 1975; Sutton et al., 1965), perceptual tasks (Campbell, Courchesne, Picton, & Squires, 1979; Johnson & Donchin, 1978; Ruchkin, Sutton, Munson, Silver, & Macar, 1981; Squires, Hillyard, & Lindsay, 1973a) and cognitive tasks (Poon, Thompson, Williams, & March, 1974; Stuss & Picton, 1978; Stuss, Toga, Hutchison, & Picton, 1980). In a guessing situation, each trial stands independently so that theoretically feedback information has relevance only for one specific trial. In both perceptual and cognitive tasks, feedback

information delivered on one trial can be used by a subject to adjust his way of responding on the next trial.

The main ERPs recorded to feedback information processing have been concerned with a late positive complex of waves (LPC) recorded from about 250-300 msec following the eliciting event. Evidence exists that the various LPC components could reflect various aspects of information processing (Friedman, Vaughan, & Erlenmeyer-Kimling, 1978a; Rösler, 1981; Ruchkin, Sutton, & Stega, 1980; Stuss et al., 1980; Stuss & Picton 1978) and could vary differently with feedback stimulus meaning depending on the paradigm used (Campbell et al., 1979; Stuss & Picton 1978; Stuss et al., 1980). The following waves have been reported: P<sub>3</sub>, P<sub>300</sub> or P<sub>3b</sub> recorded in the parieto-central region of the brain at a latency of 250-500 msec following FB delivery (for review see Campbell et al., 1979); P<sub>4</sub>, recorded in cognitive tasks in the parieto-occipital region of the brain at a latency of 650 msec (Stuss & Picton, 1978; Stuss et al., 1980); and, a slow positive wave (SW) which has been reported to be greater in various situations requiring discrimination (Ruchkin et al., 1980; Rösler, 1981). So far the variability of these waves has not been studied in relation to types of FB. Moreover, the results show that in order to delineate the contribution of the various LPC components to information processing and relate their variability with FB meaning, certain variables must be controlled. Indeed the LPC, particularly P<sub>3</sub>, has proven to be sensitive to the probability of receiving a given stimulus (Campbell et al., 1979; Friedman et al., 1973; Horst, Johnson, & Donchin, 1980), confidence level (Squires, Hillyard, & Lindsay, 1973b) and cognitive strategy adopted by a subject in dealing with the task (Friedman, Ritter, & Simson, 1978a; Picton & Stuss, 1980).

The present study compared ERPs obtained in a learning situation, which entails the use of FB information from trial to trial, with ERPs obtained in a guessing situation where each trial stands independently. Moreover, in order to increase the relevance of electrophysiological data, probability, confidence level and cognitive strategy were controlled.

Results obtained in FB studies provide us with information concerning the various sources of LPC variability. In the usual guessing paradigm subjects are requested to guess about the nature of a stimulus prior to its presentation (e.g., single or double click) and the nature of the stimulus presented confirms or disconfirms the subject's prior guess (Donchin et al., 1973; Friedman et al., 1973; Sutton et al., 1965). While feedback information has relevance only for one specific trial, in certain paradigms subjects can use the relative probability of being confirmed or disconfirmed on a trial, given the nature of preceding stimulus or "outcome probability", to improve performance. For example, if presented with two double clicks in a row, a subject can guess that he will receive a single click on a third trial, thereby increasing the probability that he will be confirmed on that trial. The amplitude of  $P_3$  has been showed to vary with outcome probability (Friedman et al., 1973) rather than with simple probability and stimulus meaning (Sutton et al., 1965). Consequently, Campbell (1979) has suggested that in a guessing paradigm  $P_3$  might reflect the effective information content of a stimulus.

Perceptual tasks that have been designed to study ERPs associated with FB have been mainly time estimation tasks (Campbell et al., 1979; Johnson & Donchin 1978; Ruchkin et al., 1981) and paradigms in which ERPs were recorded to FB following signal detections (Squires et al., 1973a). The main findings are

concerned with  $P_3$  which seems to be associated with the amount of information gathered from FB rather than with its meaning (Campbell et al., 1979). The perceptual tasks have suggested that the amount of information contained in a stimulus could be related to three main factors (Johnson, in press): subjective probability of receiving a given stimulus (Campbell et al., 1979), equivocation (Ruchkin & Sutton, 1978) and task information (Johnson, in press; Picton et al., 1978).

Campbell et al. (1979) using a time-estimation task in which the probability of receiving a positive vs a negative FB was altered by changing the time-window wherein a response was judged correct, found that  $P_3$  amplitude is related to subjective probability of being confirmed or disconfirmed. Subjective probability is the relative probability of receiving positive vs negative FB given a particular expectancy set. Expectancy was measured by subjects' confidence level in their decision prior to receiving FB. Contrary to earlier findings that had suggested that a disconfirming FB yields greater  $P_3$  than a confirming one (Squires et al., 1973a), Campbell showed that highly expected FB, being positive or negative, yields small  $P_3$ s. He suggested that  $P_3$  might reflect the amount of subjectively relevant information rather than the meaning of the information processed.

This is consistent with findings obtained in studies using ambiguous stimuli. In signal detection tasks using near threshold stimuli,  $P_3$  amplitude has been found to vary with confidence level in a detection rather than with objective signal probability (Hillyard, Squires, Bauer, & Lindsay, 1971; Squires, Squires, & Hillyard, 1975b). Highly confident hits were associated with larger and earlier  $P_3$ s than low confident detections. Ruchkin and Sutton (1978) interpreted those

results in term of an equivocation theory. They proposed that as a stimulus becomes difficult to discriminate, its effective amount of information is lowered through information loss related to subject's a posteriori uncertainty of having correctly perceived an event.

A final determinant of  $P_3$  amplitude is task information (Johnson, in press), which has been variously called "intentional engagement" (Campbell et al., 1979) and "stimulus meaning" (Picton et al., 1978). This effect suggests that task-relevant stimuli can entail different information loads depending on the task used. Hence, the same improbable stimulus elicits a larger  $P_3$  when it provides feedback information than when it is simply counted (Picton et al., 1978).

In sum,  $P_3$  seems associated with stimulus evaluation and is affected by variables that alter the amount of subjectively relevant information contained in the eliciting stimulus, such as probability and confidence level. Recent findings suggest that  $P_3$  is relatively unaffected by specific task processing requirements of the eliciting stimulus, which are reflected in later components (Duncan-Johnson, 1981; Friedman et al., 1978b; Rösler, 1981; Ruchkin et al., 1980).

Besides  $P_3$ , slow positive waves (SW) have often been reported in perceptual tasks. The majority of studies to report SW were not FB studies. SW was firstly reported by Squires, Squires, and Hillyard (1975a) and Squires, Donchin, Herring, and McCarthy, (1977) in counting tasks in response to rare task-relevant stimuli. It was recorded in the 500-750 msec latency range as a positive going parietal and negative going frontal phenomenon. Since then, it has often been reported in association with  $P_3$ . Although the SW overlaps with  $P_3$ , and seems to respond similarly to event probability and task relevancy (Donchin et al., 1978; Squires

et al., 1975a; Squires et al., 1977), it appears to be a different component from  $P_3$ . It has a different scalp distribution, varies differently with experimental manipulations and comes out as a different factor in statistical analysis (Friedman et al., 1978b; Picton & Stuss, 1980; Ruchkin et al., 1980; Squires et al., 1975a; Squires et al., 1977). Recent findings suggest that the SW can increase (become more positive) with greater processing demands (Friedman et al., 1978b; Rösler et al., 1980; Ruchkin et al., 1980).

Only one study reported a SW in response to FB stimuli delivered during a perceptual task (Ruchkin et al., 1981). In a time estimation task, FB was delivered by means of a single event or a combination of events. A first event informed the subject whether the time interval was under or overestimated; a second event informed him whether the error magnitude was within a correct limit (Positive FB) or not (Negative FB). In response to the second event, both a parietal  $P_3$  and SW were reported. Although widely distributed, SW showed similar topography as in previous reports. In this study, neither  $P_3$  nor SW was affected by FB meaning which suggests that the processing requirements were similar for both FB.

Indeed, a few studies suggest that SW can vary with task processing requirements. Ruchkin et al. (1980) compared ERPs obtained in a guessing task with those obtained in a signal detection task. In the detection task subjects had to report after stimulus presentation if they heard a single or a double click. Reward and penalty were based on the correctness of perception. In the guessing task, subjects were asked to guess before stimulus presentation about the nature of upcoming stimulus. Reward and penalty were based on the correctness of their guesses. In both the guessing and signal detection tasks  $P_3$  and SW

activities were reported. While  $P_3$  was unaffected by the task, a significant difference was found between SW topographic profiles elicited in the guessing and detection tasks. As usually reported, SW was positive at parietal sites and negative at frontal sites in both tasks; however, it was significantly more positive at the vertex in the guessing task than in the signal detection task. Ruchkin suggested that following an intermediate stage of event evaluation indexed by  $P_3$  and similar in both tasks, SW could reflect a final evaluation process that could be more complex in the guessing task than in the detection task. Indeed, while subjects' reward in the detection task was based upon a response given after the stimulus event, in guessing task subjects had to compare their actual perception of the stimulus event with their prior guess in order to determine whether they would be rewarded or penalised. The suggestion that specific task processing requirements could be indexed in positivities that follow  $P_3$  is supported by a separate study (Friedman et al., 1978b).

These authors also recorded a late positive wave (P539), defined as a peak measure that followed the usual  $P_3$  in a counting task. The fact that  $P_3$  latency did not change with processing demands while P539 latency was longer if subjects were asked to count repeated numbers in a sequence than if asked to count a specific number, led them to believe that  $P_3$  could be related to task-relevancy and stimulus probability, while later positivity could be related to response selection or other cognitive activity involved in the discrimination process.

Similar suggestions can be made from findings obtained with paradigms that used cognitive tasks. While some FB studies using cognitive tasks have reported a greater  $P_3$  amplitude to disconfirming FB (Poon et al., 1974; Stuss & Picton, 1978), recent findings suggest that if subjective probability is controlled, no  $P_3$

difference occurs between positive and negative FB (Horst et al., 1980). However, differential processing requirements associated with positive and negative FB in cognitive tasks have been found to affect the amplitude of positive components in the later latency range (Stuss & Picton, 1978; Stuss et al., 1980):

Stuss and Picton (1978) presented complex geometrical figures incorporating several informational cues. On each trial subjects formulated an hypothesis as to the correct sorting criterion and received an auditory FB so that they could alter their hypothesis until they learned the correct concept. As well as a greater P<sub>3</sub>, a parieto-occipital P<sub>4</sub> (mean latency = 647 msec) was found in false FB trials. This late positive wave appeared to be a distinct phenomenon from P<sub>3</sub> since it showed a more posterior scalp distribution and since it was especially large during periods of continual errors, disappearing when subjects became familiar with the task. These authors suggested that P<sub>4</sub> could reflect FB utilization following FB stimulus evaluation that could be indexed by P<sub>3</sub>. They also suggested that the P<sub>4</sub> phenomenon could have been more active at the beginning of the task, in the "learning to learn" phase (Stuss, 1976). In a further study (Stuss et al., 1980), this time using auditory concept formation and visual FB stimuli, P<sub>4</sub> was again reported as a parieto-occipital phenomenon. The fact that scalp distribution was similar to both FB modalities led the authors to suggest that P<sub>4</sub> could be modality independent and related to the change of perceptual processes in the light of FB information.

The relevance of positive waves occurring later than P<sub>3</sub> in learning situations was further illustrated in Rösler's learning study (1981). In this study, subjects were presented with two slides each illustrating one attribute and used FB information to learn different stimulus-response associations. ERPs were

recorded to slides presentations. The author found long term habituation of  $P_3$ , that is, with increased practice  $P_3$  amplitude decreased, suggesting a decrease in the amount of information with repeated stimulus presentations. However, a greater positivity in the 350-750 msec range was found following the second slide compared to the first one. Since response was required only after the second slide, Rösler suggested, as did Friedman et al. (1978b), that the SW could be associated with response selection.

The differentiation of the LPC is unclear (Picton & Stuss, 1980; Roth, 1978). For example, whether the P539 (parietal maximum but also seen at central and occipital leads) recorded by Friedman et al. (1978b) is similar to the  $P_4$  wave reported by Stuss and Picton (1978) and Stuss et al. (1980) also reported as a peak measure, or part of SW as suggested by Rösler (1981) is difficult to determine. Few studies have reported positivities after  $P_3$  and variations in measurements make it difficult to evaluate their equivalence across paradigms. Moreover, evidence exists that paradigms can differ in their ability to facilitate temporal dissociation of components (Friedman et al., 1978b). In that respect it has been suggested that the recording of LPC components could be facilitated if cognitive strategy was controlled (Picton & Stuss, 1980; Stuss, 1976). The present paradigm was designed to control for cognitive strategy. By rendering equivalent across subjects the way they would use FB information it was hoped to facilitate LPC component dissociation and to gain insight in ERP differences that could be expected on the basis of FB meaning.

Evidence exists in concept formation research that it is possible to control for cognitive strategy (Bruner, Goodnow, & Austin, 1977; Laughlin, 1973; Levine, 1966). In his studies of hypothesis behavior, Levine (1966) designed a concept

formation task that has been shown to encourage a focusing strategy. Focusing implies that a subject takes the first positive instance as a working hypothesis and that he uses subsequent FB, being positive or negative, to cancel irrelevant dimensions (Laughlin, 1973; Levine, 1966; Smalley, 1974). By opposition, a scanning approach implies that a subject is testing an hypothesis, keeping it until he encounters a negative FB. From an information processing point of view, focusing implies that positive as well as negative FB can lead the subject to be actively processing information. However, Levine suggested that negative FB entails a greater amount of processing i.e., while on correct trials a subject can use the material just coded as a working hypothesis, disconfirming FB implies that a subject recodes information, that is, selects from storage the complement of the just coded material. The paradigm used in the present experiment is similar to Levine's task. The main difference between the two tasks is in the number of trials used. While Levine used four to six trials, he showed that for someone using a focusing approach only two trials were necessary to do the task. The present experiment used only two trials. An additional advantage of using that type of a task and only two trials was that it is thought to control for subjective probability of being confirmed or disconfirmed on both trials, for both groups (see Methodology).

Thus, research suggests that  $P_3$  is related to the information value of a stimulus, that is, to its subjectively determined amount of information. Certain types of tasks require extended processing and the use of feedback to reevaluate responses for subsequent trials. This extended processing has been suggested to be reflected in waveforms that follow  $P_3$ . Moreover, researchers have suggested

that the recording of these late waves might be facilitated through the control of cognitive strategy.

Although the use of FB following FB evaluation has been associated with late positivities such as P<sub>4</sub> and SW, in non-FB studies late negative waves have also been associated with extended processing (for a review see Ritter, 1981). Of particular interest is a negative wave associated with semantically incongruous words in linguistic studies. This wave, termed N<sub>400</sub>, has been recorded in the latency range of 250-500 msec (Kutas & Hillyard, 1981). While N<sub>400</sub> was firstly thought to be a linguistic phenomenon (Ritter, 1981), a similar N<sub>400</sub> with a fronto-central distribution was recently found in a non-linguistic task (Stuss, Sarazin, Leech, & Picton, manuscript in preparation). These authors suggested that it could be implicated in "the activation of frontal monitoring system necessary for the supervision of complex perceptual processing". Since the frontal lobes have theoretical relevance in sorting tasks, this waveform may be reflecting required extended processing.

In the present experiment, ERPs were obtained in a learning situation and compared to ERPs obtained in a guessing situation. To succeed in the learning task subjects had to use FB information from trial to trial. By opposition FB use was irrelevant to succeed in the guessing task since each trial stood independently. Our main interest was to study how ERPs would reflect the extended processing required in the learning condition compared to the guessing one. Of secondary interest was to study how ERPs would vary with FB meaning (Positive vs. Negative FB) in these two settings.

Since the paradigm was designed to control for variables, such as probability, that are not specifically related to learning, no P<sub>3</sub> difference was

expected between groups. The extended monitoring required in the learning condition compared to the guessing one was expected to be reflected in the waveforms that follow P<sub>3</sub>. However, whether this difference would occur in the positivity or negativity that follow P<sub>3</sub> was difficult to determine. Indeed, while extended processing has been associated with late positive waves in FB studies, similar processes have been associated with late negative waves in non-FB studies.

## METHODOLOGY

### Subjects

Twenty right-handed males, aged from 25 to 39 years old ( $X = 29$ ) were randomly assigned to the Experimental and Control conditions. They were asked to avoid any kind of drugs for 24 hours and to get a good night sleep before the experimentation. Handedness was assessed using the Edinburgh handedness Inventory (Oldfield, 1971). All subjects completed a pre-experimental questionnaire to control for neurological and mental disorders (Appendix 1).

### Experimental Procedure

For all subjects, 100 series were presented, two trials in each series. Each trial was presented in a similar manner (Fig. 1). A warning tone (rise time = 10 msec; duration = 50 msec) was presented at a variable time between synchronization pulse (SP) and picture onset (from 0.4 to 0.9 sec after SP). The interval between SP and picture onset was fixed at 1.3 sec. An informative picture was presented for 500 msec on a TV screen. Response window was 1 sec following picture onset. An auditory FB was presented 1.7 sec following picture offset (rise time and duration equivalent to WS). Positive FB was signified by a 500 Hz tone and negative FB by a 2000 Hz tone. Trials were experimenter-initiated every 10 to 12 sec.

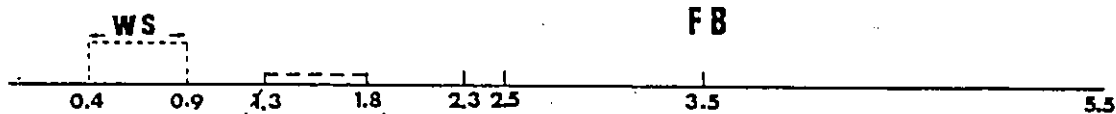
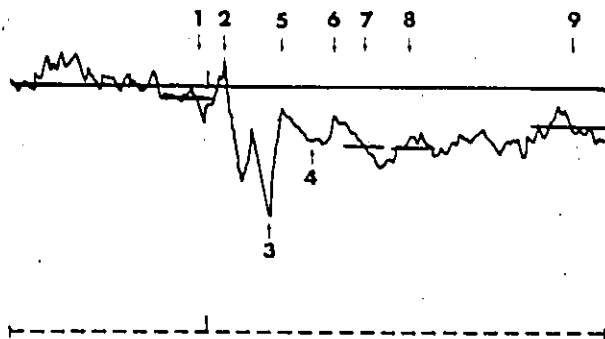
Informative pictures were presented on a 39 cm TV screen situated at eye level, 235 cm from the chair. Size of the informative stimulus was approximately 14 cm by 7 cm. Both FB tones had an intensity of 93 db SPL.

Fig. 1: Experimental Methodology. The middle portion of this figure illustrates the general timing of the experiment. The averaging sweep started 1 sec prior to FB and lasted for 3 sec. The upper right portion illustrates a sample recording taken from the vertex from an experimental subject during the second trial when negative FB was delivered; the tracing is the average of 48 trials for subject P.F. The dependent measures that were taken for analyses are numbered and identified in the upper left portion of the figure. The lower portion shows an example of a series.

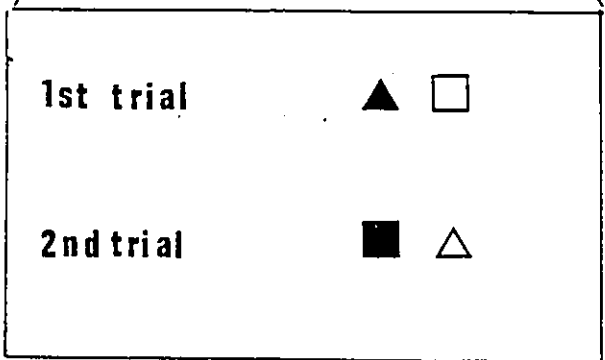
**PARADIGM**

**DEPENDENT VARIABLES**

- 1- CNV
- 2-  $N_1$
- 3-  $P_3$
- 4-  $P_4$
- 5-  $FN_{400}$
- 6-  $FN_{600}$
- 7-  $LP_{800}$
- 8-  $LP_{1000}$
- 9-  $LP_{1800}$



**EXAMPLE**



### Visual Stimuli

On each trial, subjects from both groups were presented with an informative picture consisting of two geometrical figures, a triangle and a square, one shaded and the other one unshaded, aligned horizontally (Fig. 1). Each informative picture therefore had two relevant criteria, each containing two possible dimensions: shape (triangle, square) and color (black, white). On each trial the position of a specific figure was random. Within a series of two trials, stimuli were paired as follows: on each trial, each dimension of a criterion was paired with a different dimension of the other criterion. Thus, if on the first trial the triangle was white and the square black, on the second trial the triangle was black and the square white. Given those restrictions, the total number of series was eight (Appendix 2).

### Conditions

In the Experimental condition, subjects had to learn within the two trials of a series which one of the four criteria had been randomly predetermined as correct (e.g., Black, in Fig. 1). Following picture presentation on the first trial, they responded according to their hypothesis by pressing one of two buttons, one each for their index and middle finger of their right hand, corresponding to the position of the stimulus on the screen. They then received FB informing them if the stimulus chosen contained the correct concept. For example, the subject pressed the left button on the first trial (e.g., Black triangle in Fig. 1), and received a positive FB. Using FB information on the second trial, they were able to learn the correct concept. For example, subject pressed the right button (triangle) on the second trial and received a negative FB leaving Black as the

answer. Thus depending on FB on the first trial, subjects remembered the chosen stimulus or its complement. Memory load was greater on the second trial since, independently of FB, they had to recall the first trial information to cancel an additional irrelevant dimension. FB was only delivered if subjects responded within the response window time. The interval between trials and series was 5 to 6 sec. At the end of a series subjects reported the learned concept together with the confidence level in their decision (High, Low).

Probability of being confirmed or disconfirmed on each trial was 50-50. For the first trial, each one of the two stimuli contained two out of the four possible concepts; subjects had an equal chance of being confirmed or disconfirmed whether they chose the right or the left stimulus. At the beginning of the second trial, two hypotheses remained possible. Since each stimulus contained one of the remaining tenable hypotheses, the probability of being confirmed or disconfirmed was also 50-50.

Motivation was controlled in the following manner: subjects won .05¢ each time they answered correctly at the end of a series and lost .02¢ each time they did not.

While the arrangement of stimuli has been shown to encourage a focusing strategy (Levine, 1966), this was assessed during the experiment. Subjects were requested to advise the experimenter at which time during the experimentation they decided how they would handle the task and to explain their strategy. Verbal reports were noted by the experimenter. In order to control for the amount of information provided on each trial, specific instructions describing the physical nature of stimuli and criteria were given during the practice period (Bruner et al., 1977). This procedure was equated in the control group. General instructions for both groups, during the practice period, and specific ones for each group during the experimentation are given in Appendix 3.

To prevent carry-over effects (Edwards, 1972), different subjects were used in the Control condition. Subjects were presented with the same series as for the Experimental group. On each trial, one of the four criteria was randomly determined as correct. The subjects' task was to guess on each trial which one of the two stimuli (Left or Right) contained the correct criterion and to remember the nature of the FB received for both trials of each series. At the end of a series (after second FB) they stated the nature of the FB received on both trials together with their confidence level that they remembered correctly (High, Low). Thus, as for the Experimental group, the memory load was greater on the second trial since, to succeed in the task, first trial information had to be recalled following second FB presentation.

Since each response was a guess, FB was relevant to only one specific trial. Probability of being confirmed or disconfirmed was equal on each trial since two stimuli containing an equal number of criteria were presented. Thus for both groups probability of receiving a Positive vs. a Negative FB was 50-50, on each trial.

In order to insure that subjects would be attentive to FB, they were paid .05¢ each time they remembered both FB at the end of a series and lost .02¢ each time they failed to remember both of them. Thus, whether they were right or wrong in their guess was irrelevant. However, in order to ascertain that the nature of FB received on one trial did not influence their next response, subjects verbally described their strategy for completing the task at the end of the experiment (Appendix 4).

### Electrophysiological Recordings

Electroencephalographic activity (EEG), was recorded using Beckman 16 mm Ag/AgCl electrodes fixed to the scalp with gauze and collodion. The skin was cleaned and scratched to prevent skin potential artifacts (Picton & Hillyard, 1972). Acceptable impedance level, measured with a Grass 10 Impedance meter, was less than 1 KOhm. Electrode placement was as follow: F3, F4, CZ, P3, P4, OZ, according to the 10-20 System (Jasper, 1958), referred to linked sternum/C7 electrodes (Stephenson & Gibbs, 1970). The vertical electro-oculogram (EOG) was measured with supra- and infra-orbital electrodes. Horizontal EOG electrodes were placed at left and right external canthi. A ground electrode was placed on the left arm. EEG and EOG activities were amplified using a Beckman R 611 Polygraph and Grass 7P122 amplifiers modified to have a 6.6 second time-constant. High frequency cut off was 30 Hz for the Beckman and 35 Hz for the Grass amplifier. EOG amplification was half that of all the other channels.

Prior to averaging, all trials contaminated by EOG artifacts were rejected (Picton & Hillyard, 1972). Only the trials where subjects answered correctly at the end of the series with high confidence were accepted for averaging. Trials were averaged according to condition (Experimental & Control), trial number (First & Second) and FB (Positive & Negative), so that for both groups, evoked responses were divided into four categories: First trial FB positive, First trial FB Negative, Second trial FB Positive, Second trial FB Negative. First and fourth quarters, and second and third quarters were combined for averaging to provide replications. Dependent measures used in statistical analysis were the total of both replications.

### Dependent Measures

The averaging sweep started 1 sec prior to FB and lasted for 3 sec. Baseline was arbitrarily determined from the mean amplitude recorded in the first 200 msec following the initiation of the averaging sweep. The following nine dependent measurements were selected for analysis and measured relative to the defined baseline for each subject over the four categories of averaged responses. The upper portion of Fig 1 illustrates those dependent measurements.

1. Pre FB-CNV - Average deviation in the 200 msec preceding FB onset.
2. N<sub>1</sub> - Maximum negative peak in the 75-150 post FB onset. Peak latency was defined at CZ. Amplitude at all other electrode areas was measured at the same latency.
3. P<sub>3</sub> - Maximum positive peak in the 250-500 msec post FB onset.
4. P<sub>4</sub> - Maximum positive peak in the 500-700 msec post FB onset.  
For both P<sub>3</sub> and P<sub>4</sub>, peak latency was defined as the average peak latency at P<sub>3</sub> and P<sub>4</sub> electrode sites. The amplitude at all other electrode areas was measured at this averaged latency.

Frontal negativities. An index of the post FB negativity was taken within two ranges.

5. FN<sub>400</sub> - Maximum negative peak in the 350-550 msec post FB.
6. FN<sub>600</sub> - Maximum negative peak in the 550-750 msec post FB.  
For both FN<sub>400</sub> and FN<sub>600</sub>, peak latency was defined as the averaged peak latency at F3 and F4 electrode sites. All other electrode areas were measured at this averaged latency.

Late slow positive waves. An index of the late positive activity was taken at each derivation from the maximum positive averaged smoothed deviation within three ranges.

7. LP<sub>800</sub> - averaged deviation in the 700 to 900 msec post FB.
8. LP<sub>1000</sub> - averaged deviation in the 900 to 1100 msec post FB.
9. LP<sub>1800</sub> - averaged deviation in the last 400 msec of the averaging sweep (1600-2000 Post FB).

### Statistical Analysis

A two factor univariate analysis of variance with repeated measures on one factor (BM2P-P2V, Dixon & Brown, 1979) was used for each dependent measurement, according to the basic hypothesis.

The factors were: A) CONDITION (Experimental and Control); B) TRIAL (First and Second); C) FB (Positive and Negative); and, D) ELECTRODE PLACEMENT (CZ, OZ, F3, F4, P3, and P4). The following analyses were completed.

1. GROUP x FB. Within each trial (First and Second) a two way univariate analysis of variance with repeated measures on one factor was done. The fixed factor was CONDITION and the repeated one, FB. This was performed at each electrode placement.

2. GROUP x TRIAL. Within each FB (Positive and Negative) a two way univariate analysis of variance with repeated measures on one factor was done. The fixed factor was CONDITION and the repeated one was TRIAL. The analysis was also performed at each electrode placement.

Accepted level of significance was set at  $p \leq 0.05$ . Significant main effects were analyzed using Tukey's "honestly significant difference statistic". When significant interaction occurred the procedure for testing simple main effects followed that of Winer (Winer, 1971, p. 544). Degrees of freedom were 1 for the numerator and 18 for the denominator.

## RESULTS

Behavioral

After approximately 15 series, subjects from the Experimental group reported their strategy. All subjects reported using a focusing strategy in dealing with the task. On the first trial, most of them responded in a fixed manner (four according to shape; five according to position). On this first trial, if positive FB was delivered they remembered their choice stimulus and if negative FB was delivered they remembered the complementary one. Both positive and negative FB required registration in memory of two dimensions and retention of this information for comparison to the second trial outcome. For most of the subjects, the motor response on the second trial was according to the same fixed manner as for the first one. On this second trial both FB signals required comparison of the choice stimulus with the information in memory from the first trial. Positive FB entailed passive exclusion of one dimension while negative FB entailed active exclusion of one dimension. Approximately 90% of the series where subjects could not find the correct criterion occurred in the fifteen first series. Wrongly answered series were automatically rejected from analysis.

Two out of the ten control subjects reported having responded in a completely random fashion on both trials of all series. The remaining subjects reported that they tried to respond in such a way that they would receive positive FB to one or both trials of a series. Some reported having done so for 30% of the trials, others for all trials. The general method used was to calculate the probability of being confirmed or disconfirmed over a fixed number of trials (from 2 to 6 depending on subjects), and to respond accordingly. About 5% of the series were rejected in the control group because subjects failed to remember the FB received to one or both trials of a series.

### Grand Averaged Data and Statistical Results

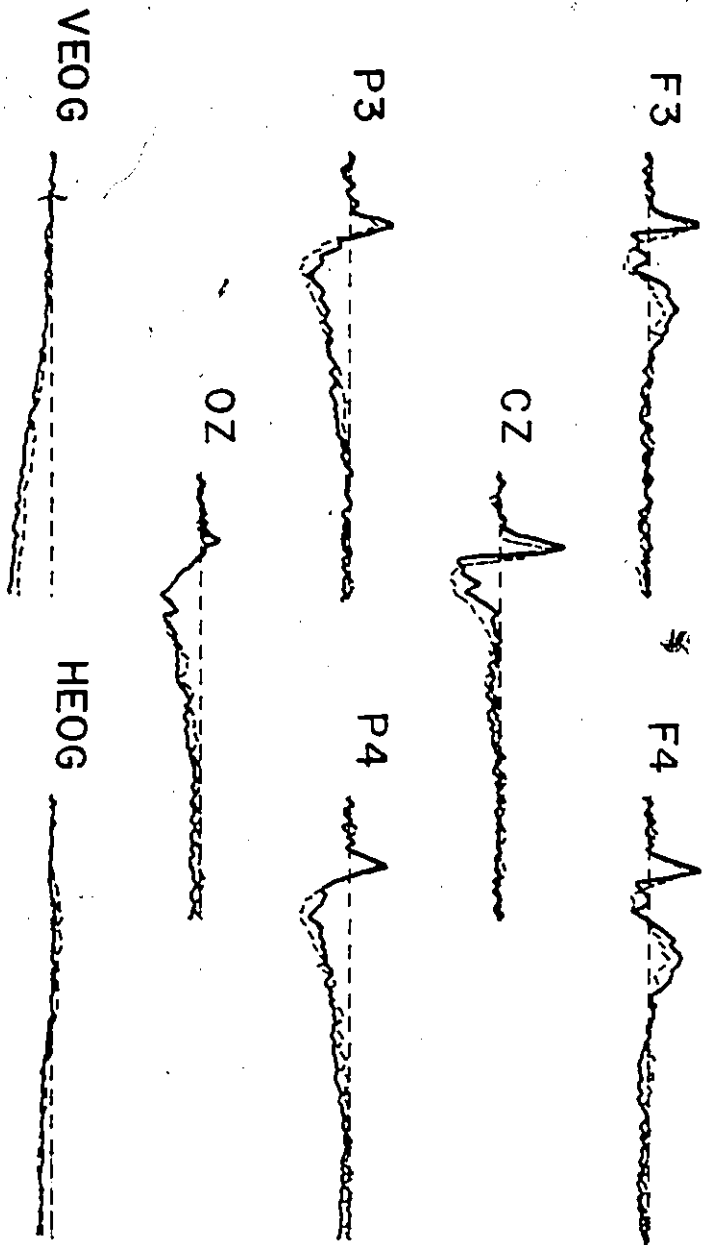
In both groups, 10 to 50% of the trials were rejected because of EOG artifacts. GROUP x FB analysis revealed a significant Pre FB-CNV interaction. Within the second trial, Pre FB-CNV were equivalent except for the Experimental FB Positive category, which was significantly more negative at one electrode area. No a priori reason existed for such a difference which suggested a possible confounding effect of baseline. All subsequent statistics were completed subtracting the CNV from each dependent measurement at all electrode placements. The original means and standard deviations for the all dependent measures across CONDITION, FB, TRIAL, and ELECTRODE placements are presented in Appendix 5. The revised means, i.e., after Pre FB-CNV subtraction, are presented according to their scalp distributions across categories of averaging for each group in Appendix 6. The following results are based upon the revised scores, and figures are done using CNV as baseline. F tables of significant results are presented in Appendix 7.

Fig. 2 (A, B, C, and D) shows superimposed grand averaged data for each group obtained at all electrode areas, for each of the four categories of averaging. P<sub>3</sub> (mean latency = 352 msec for the Experimental group and 341 msec for the Control group) was consistently recorded maximally at both parietal leads. A clearly defined P<sub>4</sub> (mean latency = 585 msec for the Experimental group and 574 msec for the Control group) was present in half the subjects in each group. P<sub>4</sub> was recorded as a parieto-occipital phenomenon, of maximum amplitude over the left hemisphere except for the control group on the first trial where it was maximum at both parietal leads. P<sub>4</sub> was negative or near baseline frontally. LP<sub>800</sub> was also recorded as a parieto-occipital phenomenon and maximum over the left hemisphere.

Fig. 2: A-B-C-D. Superimposed grand averaged data for each group obtained at all electrode areas for each of the four averaging categories: A) First trial Feedback Positive; B) First trial Feedback Negative; C) Second trial Feedback Positive; and D) Second trial Feedback Negative. A greater frontal negativity for the Experimental group than for the Control group was apparent within the four categories of averaging. The Experimental group also showed greater posterior positivity, especially during the Second trial.

A

FIRST TRIAL  
FEEDBACK POSITIVE

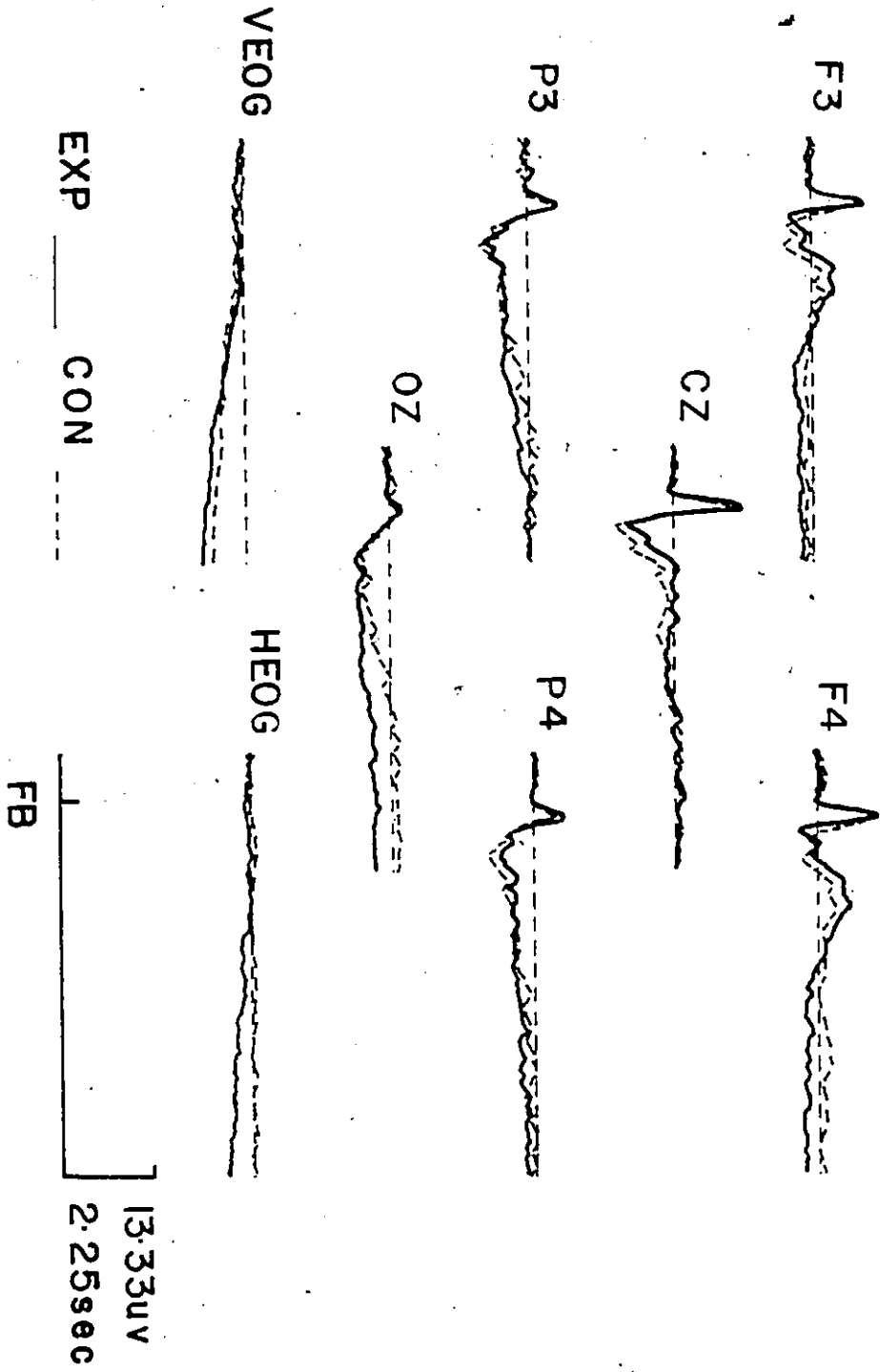


EXP \_\_\_\_\_ CON - - - -

13.33uV  
2.25sec  
FB

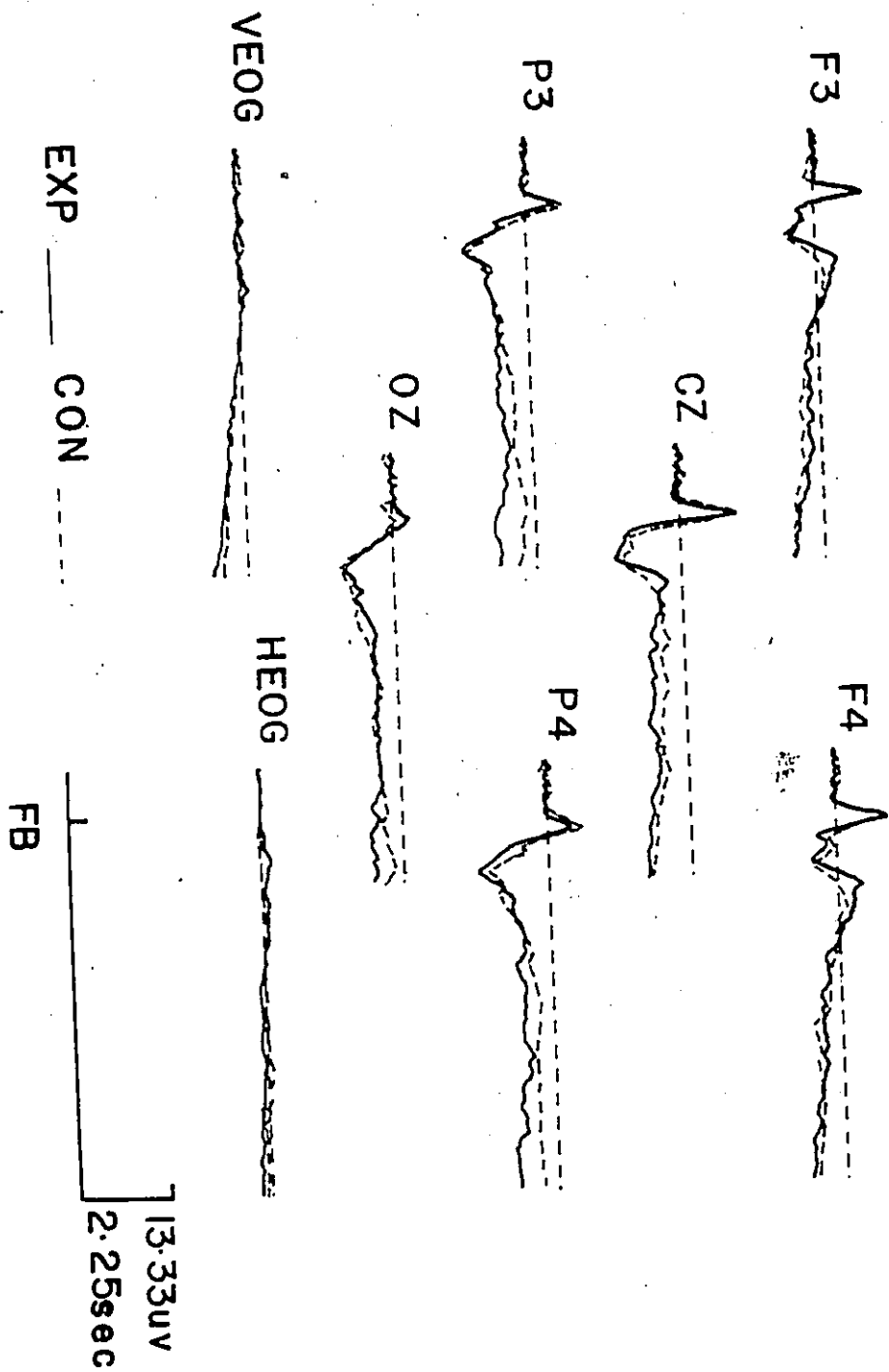
B.

FIRST TRIAL  
FEEDBACK NEGATIVE



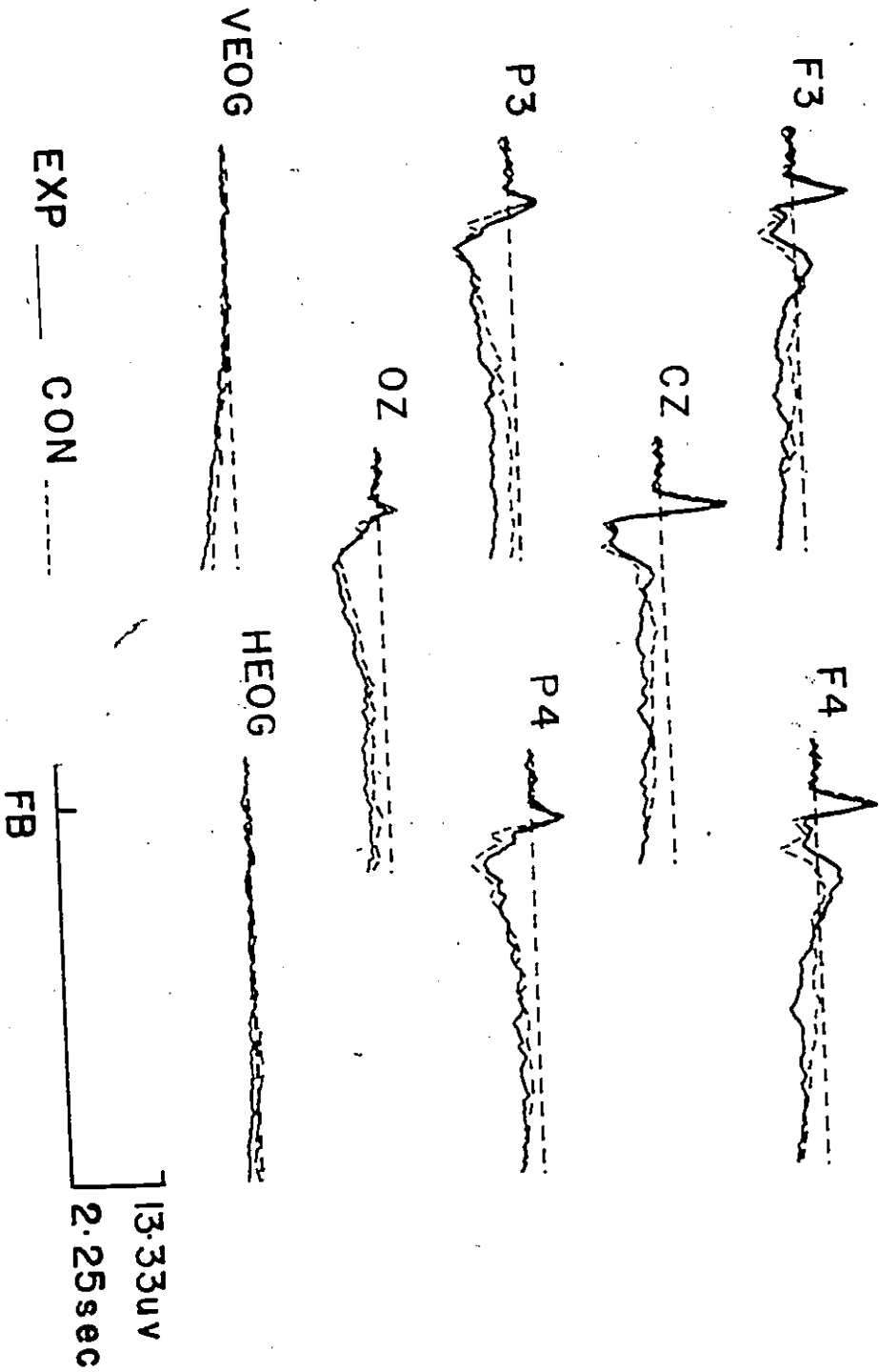
C

SECOND TRIAL  
FEEDBACK POSITIVE



D

SECOND TRIAL  
FEEDBACK NEGATIVE



LP<sub>1000</sub> was recorded as a positive wave with parieto-occipital maximum on the first trial, becoming more widely distributed yet still maximum posteriorly on the second trial. LP<sub>1800</sub> was of small amplitude on the first trial and a widely distributed positive wave on the second trial. Both FN<sub>400</sub> and FN<sub>600</sub> were recorded as frontal negative phenomena, being positive posteriorly. FN<sub>400</sub> was of small amplitude at CZ and FN<sub>600</sub> was negative on the first trial at CZ and positive at this electrode site on the second trial.

#### I. GROUP x FB

Within First trial. No significant main or interaction effects were found at any electrode placement.

Within Second trial. There was no significant main group effect on any of the dependent measures. No main FB effect or interaction were found for N<sub>1</sub>, P<sub>4</sub>, FN<sub>400</sub>, FN<sub>600</sub>. For both groups, a significantly greater positivity, as indexed by the variables P<sub>3</sub>, LP<sub>1000</sub> and LP<sub>1800</sub>, was found in response to Positive FB compared to Negative FB at CZ only. This was also significant for P<sub>3</sub> at the P3 electrode site.

Conversely, at OZ only, LP<sub>800</sub> was significantly greater for Negative FB than Positive FB for both groups. Significant interaction effects were found for P<sub>3</sub> at F4 electrode site, LP<sub>1800</sub> at P3 and P4 electrode sites. Simple main effects showed that at the P3 electrode site the variable LP<sub>1800</sub> was significantly greater to Positive FB than Negative FB for the Experimental group only.

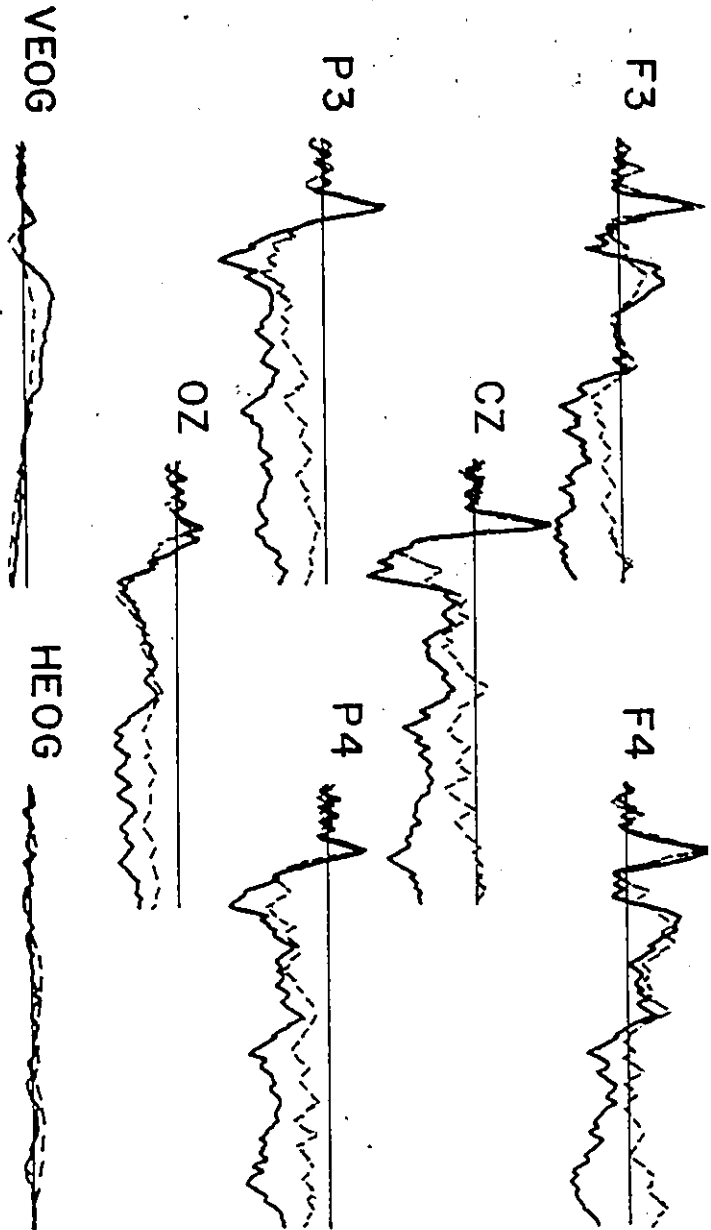
## II. GROUP x TRIAL

Within Positive FB. There was no significant group difference independent of trials on any of the dependent measures. While no main trial or interaction effects were found for  $N_1$  and  $FN_{400}$ , post FB positivities in general were significantly greater on the second trial than on the first one for both groups. This was indexed by the following variables:  $P_3$  (at all electrode sites except F4);  $P_4$  (at CZ, F4, P3 and P4);  $LP_{800}$  and  $LP_{1000}$  (at all electrode sites except OZ); and  $LP_{1800}$  (at all electrode areas).  $FN_{600}$  was also significantly more positive on the second trial at CZ, F4 and P3. Fig. 3 shows superimposed data of each trial from an experimental subject at all electrode areas. No significant interaction was found. In sum, for both groups a greater positivity was found on the second trial than on the first trial when positive FB was delivered.

Within Negative FB. A main group effect was found for  $FN_{400}$  which was significantly larger for the Experimental group than the Control group at F3 and F4 electrode sites regardless of trial. Fig. 4 (A and B) shows the superimposed data of two subjects, one from each group, obtained at all electrode areas on each trial. Possibly because of common variability with the frontal negativities,  $P_4$  was also significantly more negative for the Experimental group at the F4 electrode site. Another main group effect was found for  $LP_{1800}$  which was more positive at OZ for the Experimental group.

No main trial effect or interaction were found for  $N_1$  and  $LP_{1000}$  responses. Although not as pronounced, the greater positivity found on second trial within Positive FB also appeared within Negative FB:  $P_3$  (at all electrode sites except F3 and F4),  $P_4$  (at P3 and P4),  $LP_{800}$  (at F4) and  $LP_{1800}$  (at all electrode areas

Fig. 3: Superimposed averages of First and Second trial data obtained at all electrode placements by an Experiment subject (G.L.H.) when Positive FB was delivered. The tracing for the First trial is the average of 52 trials and the one for the Second trial is the average of 34 trials.



SEC \_\_\_\_\_ FIR \_\_\_\_\_

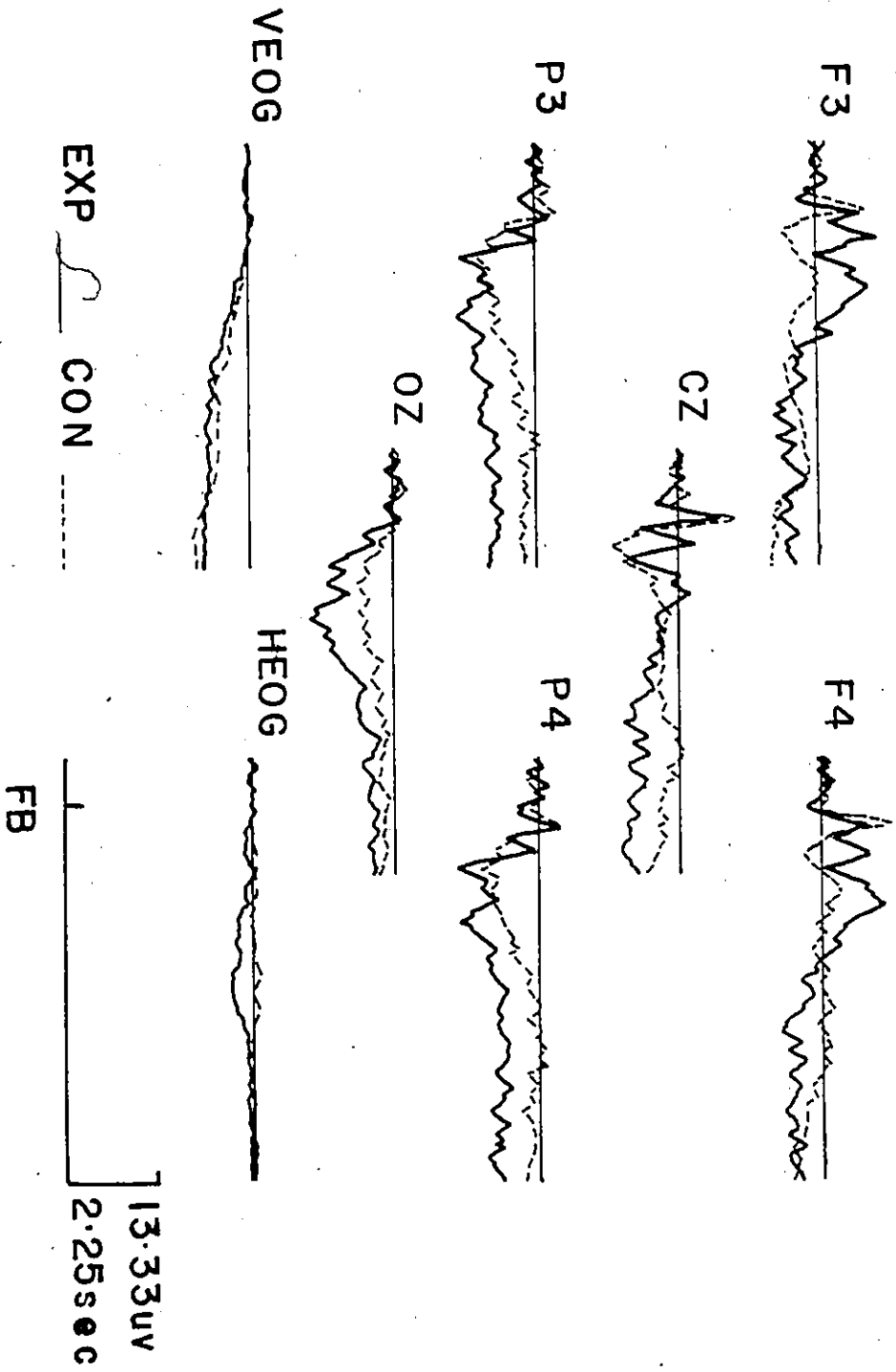
13.33 uV  
2.25 sec

FB

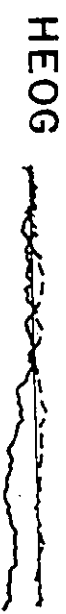
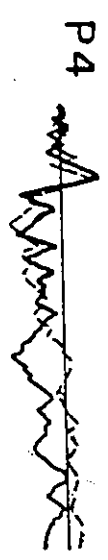
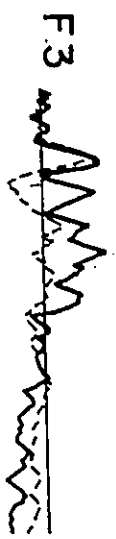
5

Fig. 4: A-B. Superimposed data of two subjects, one from each group, obtained at all electrode placements during Negative FB trials. A) First trial Negative FB; and, B) Second trial Negative FB. The Control data (C.R.) are the average of 45 trials for the First trial and 35 trials for the Second trial. The Experimental data (R.N.) is the average of 37 trials for both the First and Second trials.

A.



B.



EXP \_\_\_\_\_ CON \_\_\_\_\_

FB |-----| ] 13.33 uV  
 2.25 sec

except OZ). This greater positivity for the second trial was also found for FN400 posteriorly (P3, P4, OZ) and for FN600 at all electrode areas. A significant interaction was found for the P<sub>3</sub> variable at F4 electrode site. The simple main effect showed that P<sub>3</sub> was greater on the second trial for the control group only.

In sum, as for the results obtained to Positive FB, a greater positivity was found for second trial than first trial to Negative FB. The Experimental group showed greater frontal negativity than the Control group on both Negative FB trials.

## DISCUSSION

Feedback is a common way of updating and monitoring performance.

Controlling for various factors, this research attempted to study ERPs to FB use in a concept formation task, and assessed the effects of relevance of FB (Guessing vs Learning), FB meaning (Positive vs Negative), as well as FB order (First vs Second trial).

The processing demands imposed by the task in the Experimental condition were clearly different from those imposed in the Control condition. In the Control condition, subjects were asked to guess on each trial of a series which stimulus contained the correct criterion and to remember the nature of FB delivered on each trial. Thus, FB was relevant for one specific trial and theoretically, whether FB was positive or negative, was irrelevant for future responding. Since subjects reported their verbal response at the end of each series, the memory load was greater following second FB presentation as they had to remember FB information from both trials. On each trial in the Experimental condition, subjects had to use FB information to cancel irrelevant dimensions in order to learn the concept. Both positive and negative FB could be used to cancel dimensions but negative FB required a greater amount of processing since it implied active exclusion of dimensions (Levine, 1966). Memory load was also greater on the second trial since FB use on that trial entailed a comparison of the choice stimulus with the one in memory from the first trial.

In spite of the difference in the relevance of FB for future responding (Guessing vs Learning), no group differences were found in late positive waves, as previous FB studies would have suggested (Stuss & Picton, 1978; Stuss et al.,

1980). Contrary to previous studies, however, the present one intended to control for a variety of factors. For both groups, the probability of receiving a given FB stimulus was equal on each trial. The paradigm also controlled for cognitive strategy, and subjective reports were used to complete this assessment. Moreover, an attempt was made to control for confidence level and motivational factors. The fact that no group differences were found in late positive wave might then be attributable to the elimination of important sources of late positive wave variability through the control of the variables just mentioned. However, the absence of group differences in late positivities might also be due to the behavior of the Control subjects, whose responses were affected by FB meaning.

In spite of this difficulty with the Control condition, a significant group effect was found for FN<sub>400</sub> (latency: 350-550 msec) with the experimental group showing greater frontal negativities than the Control group to Negative FB during both trials. The lack of robustness of this statistical result suggests that this difference should be interpreted with caution. However, many factors suggest that to ignore this result for this reason could lead to a type II error.

In the present experiment, this negativity was strictly a frontal phenomenon. The frontal cortex has been suggested to be important in FB use. It has been hypothesized to be involved in change and maintenance of strategies and in the selection and monitoring of appropriate behaviors; damage to this area results in an inability to use FB (Stuss & Benson, in press). Compared to the Control group who only had to remember FB information, the Experimental group had to use FB to cancel irrelevant dimensions. In using a focusing strategy, both positive and

negative FB allowed for dimension cancellations; however, negative FB entailed active exclusion since subjects had to select from storage the complement of their actual choice stimulus. An examination of the grand averaged data suggests that the phenomenon underlying FN<sub>400</sub> was active for both Positive and Negative FB. However, statistical results reached significance only for Negative FB. It is suggested that FN<sub>400</sub> could reflect selection and monitoring processes involved in the cancellation of dimensions, and that these processes although present for both Positive and Negative FB, were most active for Negative FB.

Compared to the present task, that used by Stuss and Picton (1978) was more complex and did not control for either cognitive strategy or for probability of FB stimuli. P<sub>4</sub>, which was also associated with negative FB, came with repeated errors and tended to disappear when subjects became familiar with the task, suggesting that it might be more related to change of strategy. It is possible that FN<sub>400</sub> and P<sub>4</sub> are parts of a single Negative-Positive complex, and that whether this complex shows positive or negative deflection is dependent upon factors such as cognitive strategy. The fact that Stuss (1976) recorded large N<sub>3s</sub> (X latency: 522 msec) when P<sub>4</sub> was absent seems to corroborate this.

Frontal negativities in the latency range of 250-500 msec are relatively newly reported phenomena. Although they were originally reported in linguistic studies (Ritter, 1981), they have also been associated with "the activation of frontal monitoring systems" in non-linguistic tasks (Stuss et al., manuscript in preparation). Similar processes might have been associated with the cancellation of dimensions in the present experiment. However, the lack of robustness of the statistical results suggests that replications are necessary to confirm the present findings.

A significant trial effect was found for both Experimental and Control groups, with the Second trial showing greater general positivity of the waveforms, starting at P<sub>3</sub> latency. This finding was more evident within Positive FB, where no negativity was superimposed, than within Negative FB. This might be

attributable to the fact that memory load was greater on the second trial than on the first one. Indeed, following second FB presentation, the Control subjects had to recall the FB received on the first trial as well as the second one to succeed in the task. Similarly, the Experimental subjects had to recall first trial outcome on the second trial in order to cancel an additional irrelevant dimension. Rösler (1981) and Ruchkin et al. (1980) have also found a greater general positivity following second stimulus presentation which they associated to response selection and final evaluation processes.

An unexpected finding concerned LPC variability to FB meaning during the second trial. A significantly greater positivity was found at CZ in response to Positive FB compared to Negative FB. This result is at odds with that of previous studies (Poon et al., 1974; Squires et al., 1973a; Stuss & Picton, 1978). Various factors could be put forward to tentatively explain this difference, such as the subject's option for the control group (Sutton, Tueting, & Hammer, 1978) and a less active frontal negativity for Positive FB than Negative FB for the Experimental group.

Thus the present findings suggest that information processing associated with FB use in a learning situation, when probability, confidence level and cognitive strategy are controlled, could be reflected in ERP components that occur later than P<sub>3</sub>. FB meaning per se seems to have little effect on ERPs, since its effect was showed at only one electrode area. Instead it appears that the processes

underlying cognitive strategy are more important. In the present study, a focusing strategy was used by subjects and in such a situation the selection and monitoring processes associated with FB use seem to be associated with a greater frontal negativity. It is also suggested that the greater memory load implied following second FB presentation, is associated with greater late slow positivity. The lack of robustness of the statistical results suggests, however, that more research is necessary to confirm those findings.

In that respect, group differentiation of the late frontal negativity could be ascertained in the present paradigm through the use of an improved control condition. For example, a guessing task could still be used, but memory load could be increased by asking the subjects to remember their choice stimulus as well as FB received on both trials, thereby decreasing the likelihood that they would use FB information. The hypothesized FN<sub>400</sub> - P<sub>4</sub> complex could be studied by using the same paradigm as the one used for the present experiment with a varying number of additional overlearning trials, and by changing the criterion in force without warning. Separate averaging of the first false FB trials obtained in the "learning to learn" phase, that is before subjects have established their strategy, could also illustrate this phenomenon.

## REFERENCES

- Bruner, J. S., Goodnow, J. J., & Austin, G. A. A Study of Thinking. New York: Wiley & Sons Inc., 1977.
- Campbell, K. B., Courchesne, E., Picton, T. W., & Squires, K. C. Evoked potential correlates of human information processing. Biological Psychology, 1979, 8, 45-68.
- Dixon, W. J., & Brown, M. B. Biomedical Computer Program P-Series. Berkely: University of California Press, 1979.
- Donchin, E., Kubovy, M., Kutas, M., Johnson, R. Jr., & Hering, R. I. Graded changes in evoked response (P300) amplitude as a function of cognitive activity. Perception and Psychophysics, 1973, 14, 319-324.
- Donchin, E., Ritter, W., & McCallum, W. C. Cognitive psychophysiology: the endogenous components of the ERP. In E. Callaway, P. Tueting, & S. H. Koslow (Eds.): Event Related Brain Potentials in Man. New York: Academic Press, 1978, Pp. 349-411.
- Duncan-Johnson, C. C. P300 latency: a new metric of information processing. Psychophysiology, 1981, 18, 207-215.
- Edwards, A. L. Experimental Design in Psychological Research. New York: Holt, Rinehart & Winston, 1972.
- Friedman, D., Hakerem, G., Sutton, S., & Fleiss, J. Effect of stimulus uncertainty on the pupillary dilatation response and the vertex evoked potential. Electroencephalography and Clinical Neurophysiology, 1973, 34, 475-484.

- Friedman, D., Ritter, W., & Simson, R. Analysis of nonsignal evoked cortical potentials in two kinds of vigilance tasks. In D. A. Otto (Ed.): Multidisciplinary Perspectives in Event-Related Brain Potentials Research. Washington, D.C.: U.S. Environmental Protection Agency, 1978, Pp. 194-197.
- Friedman, D., Vaughan, H. G. Jr., & Erlenmeyer-Kimling, L. Stimulus and response related components of the late positive complex in visual discrimination tasks. Electroencephalography and Clinical Neurophysiology, 1978b, 45, 319-330.
- Geisser, S., & Greenhouse, S. W. An extension of Box's results on the use of the F distribution in multivariate analysis. Annals of Mathematical Statistics, 1958, 29, 885-891.
- Hillyard, S. A., Squires, K. C., Bauer, J. W., & Lindsay, P. H. Evoked potential correlates of auditory signal detection. Science, 1971, 172, 1357-1360.
- Horst, R. L., Johnson, R. Jr., & Donchin, E. Event-related brain potentials and subjective probability in a learning task. Memory and Cognition, 1980, 8 (5), 476-488.
- Jasper, H. H. The ten-twenty electrode system of the International Federation. Electroencephalography and Clinical Neurophysiology, 1958, 10, 371-375.
- Johnson, R. Jr. P300: A model of the variables controlling its amplitude. Paper presented at the Sixth International Conference on Event-Related Slow Potentials of the Brain, 1981, in press.
- Johnson, R., & Donchin, E. On low P300 amplitude varies with the utility of the eliciting stimuli. Electroencephalography and Clinical Neurophysiology, 1978, 44, 424-437.

- Keppel, G. Design and Analysis: A Researcher's Handbook. Englewood Cliffs, N.J.: Prentice-Hall, 1973.
- Kutas, M., & Hillyard, S. A. Event-related brain potentials (ERPs) elicited by "novel" stimuli during sentence processing. Cognition, Information Processing and Language Abstracts of Posters at the Sixth International Conference on Event Related Slow Potentials of the Brain. Lake Forest, Illinois, 1981.
- Laughlin, P. R. Selection strategies in concept attainment. In R. L. Solso (Ed.): Contemporary Issues in Cognitive Psychology. The Loyola Symposium, Washington, 1973.
- Levine, M. Hypothesis behavior by humans during discrimination learning. Journal of Experimental Psychology, 1966, 71, 331-358.
- Oldfield, R. C. The assessment and analysis of handedness: the Edinburgh Inventory. Neuropsychologia, 1971, 9, 97-113.
- Picton, T. W., Campbell, K. B., Baribeau-Braun, J., & Proulx, G. B. The neurophysiology of human attention: a tutorial review. In J. Requin (Ed.): Attention and Performance VII. Hillsdale, New Jersey: Laurence Erlbaum, 1978, Pp. 45-67.
- Picton, T. W., & Hillyard, S. A. Cephalic skin potentials in electroencephalography. Electroencephalography and Clinical Neurophysiology, 1972, 33, 419-424.
- Picton, T. W., & Stuss, D. T. The component structure of the human event-related potentials. In H. H. Kornhuber & L. Deecke (Eds.): Motivation, Motor and Sensory Processes of the Brain. Progress in Brain Research, Vol. 54, North Holland: Elsevier, 1980, Pp. 17-49.

- Poon, L. W., Thompson, L. W., Williams, R. B. Jr., & Marsh, G. R. Changes of antero-posterior distribution of CNV and late positive component as a function of information processing demands. Psychophysiology, 1974, 11, 660-673.
- Ritter, W. Cognition and ERPs: the relation of post-stimulus negative potentials and cognitive processes. Panel Reports, Sixth International Conference on Event-Related Slow Potentials of the Brain, Lake Forest, Chicago, 1981.
- Rösler, F. Event-related brain potentials in a stimulus-discrimination learning paradigm. Psychophysiology, 1981, 18, 447-455.
- Roth, W. T. How many late positive waves are there? In D. A. Otto (Ed.): Multidisciplinary Perspectives in Event-Related Brain Potentials Research. Washington, D.C.: U.S. Environmental Protection Agency, 1978, Pp. 170-173.
- Ruchkin, D. S., & Sutton, S. Equivocation and P300 amplitude. In D. A. Otto (Ed.): Multidisciplinary Perspectives in Event-Related Brain Potentials Research. Washington, D.C.: U.S. Environmental Protection Agency, 1978, Pp. 175-178.
- Ruchkin, D. S., Sutton, S., Munson, R., Silver, K., & Macar, F. P300 and feedback provided by absence of the stimulus. Psychophysiology, 1981, 18, 271-282.
- Ruchkin, D. S., Sutton, S., & Stega, M. Emitted P300 and slow wave event-related potentials in guessing and detection tasks. Electroencephalography and Clinical Neurophysiology, 1980, 49, 1-14.
- Ruchkin, D. S., Sutton, S., & Tueting, P. Emitted and evoked P300 potentials and variation in stimulus probability. Psychophysiology, 1975, 12, 591-595.

- Smalley, N. S. Modes of extracting in concept attainment as a function of selection versus reception paradigm. Journal of Experimental Psychology, 1974, 102, 56-61.
- Squires, K. C., Donchin, E., Hering, R. I., & McCarthy, G. On the influence of task relevance and stimulus probability on event-related potentials components. Electroencephalography and Clinical Neurophysiology, 1977, 42, 1-14.
- Squires, K. C., Hillyard, S. A., & Lindsay, P. H. Cortical potentials evoked by confirming and disconfirming feedback following an auditory discrimination. Perception and Psychophysics, 1973a, 13, 25-31.
- Squires, K. C., Hillyard, S. A., & Lindsay, P. H. Vertex potentials evoked during auditory signal detection: relation to decision criteria. Perception and Psychophysics, 1973b, 14, 265-272.
- Squires, K. C., Squires, N. K., & Hillyard, S. A. Decision related cortical potential during an auditory signal detection task with cued observation intervals. Journal of Experimental Psychology: Human Perception and Performance, 1975b, 104, 268-279.
- Squires, N. K., Squires, K. C., & Hillyard, S. A. Two varieties of long-latency positive waves evoked by unpredictable auditory stimuli in man. Electroencephalography and Clinical Neurophysiology, 1975a, 38, 387-401.
- Stephenson, S. A., & Gibbs, F. A. A balanced non-cephalic reference electrode. Electroencephalography and Clinical Neurophysiology, 1970, 28, 360-367.
- Stuss, D. T. Electrophysiological Correlates of Human Concept Learning. Thesis material presented at the University of Ottawa, 1976, unpublished data.

- Stuss, D. T., & Benson, D. F. Neuropsychological studies of the frontal lobes. In E. D. Caine and H. Weingartner. Neuropsychiatry: An Integration of Themes and Research. Baltimore: Williams and Wilkins, in press.
- Stuss, D. T., & Picton, T. W. Neurophysiological correlates of human concept formation. Behavioral Biology, 1978, 23, 135-162.
- Stuss, D. T., Sarazin, F., Leech, E., & Picton, T. W. Evoked potentials during naming. Manuscript in preparation.
- Stuss, D. T., Toga, A., Hutchison, J., & Picton, T. W. Feedback Evoked Potentials During an Auditory Concept Formation Task. In H. H. Kornhuber and L. Deecke (Eds.): Motivation, Motor and Sensory Processor of the Brain. Progress in Brain Research, Vol. 54, North Holland: Elsevier, 1980, Pp. 403-409.
- Sutton, S., Braren, M., & Zubin, J. Evoked-potential correlates of stimulus uncertainty. Science, 1965, 150, 1187-1188.
- Sutton, S., Tueting, P., & Hammer, M. Evoked potentials and feedback. In D. A. Otto (Ed.): Multidisciplinary Perspectives in Event-Related Brain Potentials Research. Washington, D.C.: U. S. Environmental Protection Agency, 1978, Pp. 184-189.
- Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1971.
- 5

APPENDIX 1

PRE-EXPERIMENTAL QUESTIONNAIRE

## PRE-EXPERIMENTAL QUESTIONNAIRE

Have you ever consulted a doctor for neurological problems (Severe headaches, epilepsy or any other disorder of the nervous system).

YES:

NO:

Have you ever been treated for psychological difficulties (Depression, severe anxiety)? etc...

YES:

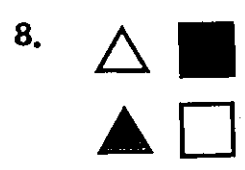
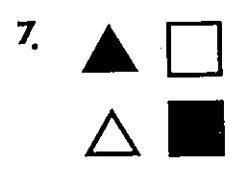
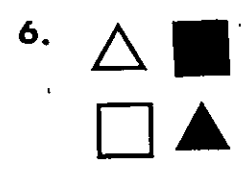
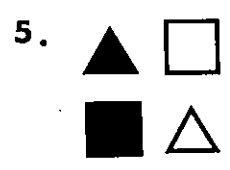
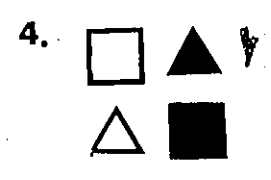
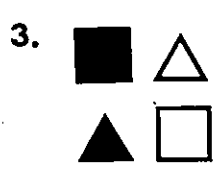
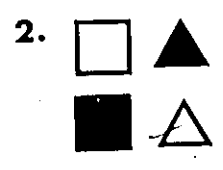
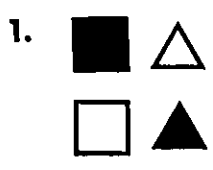
NO:

7

.APPENDIX 2

ILLUSTRATIONS OF THE EIGHT SERIES USED DURING THE EXPERIMENT

# VISUAL STIMULI



APPENDIX 3

GENERAL AND SPECIFIC INSTRUCTIONS FOR EXPERIMENTAL AND CONTROL GROUPS

GENERAL INSTRUCTIONS  
ENGLISH

This experiment is designed to study brain waves associated with feedback reception. It is divided into two parts: a practice period and the experimentation.

PRACTICE

This part is to acquaint yourself with the procedure: distinguish positive from negative feedback (auditive stimuli), to familiarize yourself with the response box and to learn when the blink (blinking affects brain waves, so it has to be controlled).

You will first hear a tone through the earphones. From 0.4 sec to 0.9 sec later a complex picture without meaning will come on the TV screen. A white spot is fixated at the center of the screen. I ask you to fixate it during the experiment. From the moment the picture is on, you have 1 sec to press one of the buttons from the response box (the white and the red are used; you can press any one for the practice period). If you don't answer quickly enough, a note will appear at the bottom of the screen ("Vas-y" - "Let's go"). If you answer in time you will then hear a second sound, the feedback tone (without meaning for the practice period). During the experimental period, a low tone will tell you that you made a "correct" choice, a high tone, that you made an "incorrect" choice. This feedback will be delivered at a fixed interval following the appearance of the picture on the screen, that is 2.1 sec. You can't blink from the moment you hear the first tone to about 5 sec following feedback delivery. I'll give you as many trials as necessary. You'll see, at the end of the practice period you will decide of the moment of trial presentation, by fixating after having blinked between trials (which I can follow from your EEG tracing). Try to blink many small times instead of closing eyes for a time when you have a need to blink.

INSTRUCTIONS FOR CONTROL GROUP  
ENGLISH

The timing for the experimentation is exactly the same as for the practice period, buttons (white and red) used and feedback also. You also have to fixate the white spot on the screen during trials. The task changes however.

From now on, two stimuli aligned horizontally will appear on the screen on each trial. Always, one of them will be a triangle and the other one a square; position is random. Sometimes the triangle will be white and the square black, sometimes it will be the opposite.

You will be presented with series of two trials. On each trial one of those stimuli is "correct" in the sense that it has been decided like that randomly. Each trial contain four criteria (triangle, square, white, black) and it is randomly that one of those has been determined to be "correct" on each trial. I want you to tell me, after each trial, which one of the stimuli you think is correct (on the response box the right button correspond to the right stimulus and the left one to the left stimulus). Use index and middle finger of the right hand to respond. The feedback you will receive will tell you if you are right or not. Trials are presented in groups of two. Don't forget however that those two trials are absolutely independent from one another. Your task is to guess, on each trial, which of the two stimuli contains the right criterion. I will also ask you to tell me after each series of two trials which feedback you have received on those two trials, and to tell me if your confidence is High or Low that you remember those feedback correctly. The interval between trials is approximately 5 to 6 sec. You will win .05¢ each time you will remember the nature of the feedback received and lose .02¢ each time you wont. GOOD LUCK.

INSTRUCTIONS FOR EXPERIMENTAL GROUP  
ENGLISH

The timing for the experimentation is exactly the same as for the practice period: buttons (white and red) used and feedback also. You also have to fixate the white spot on the screen during trials. The task changes however.

From now on, two stimuli aligned horizontally will appear on the screen on each trial. Always, one of them will be a triangle and the other one a square; position is random. Sometimes the triangle will be white and the square black, sometimes it will be the opposite.

You will be presented with series of two trials, each of those series being a problem. For each problem one of the four criteria (triangle, square, white and black) is correct in the sense that it has been predetermined like that. After each trial I will ask you to tell me which one of the two stimuli you think is correct (on the response box, the right button correspond to the right stimulus, and the left button to the left stimulus). Use the index and middle finger of the right hand to respond. The nature of feedback you'll receive will tell you if you made the right choice. The procedure is the same for both trials, so that you will be able to learn which criterion is correct within two trials (triangle, square, white, black). The criterion is always single that is there is no such response as "white triangle" for example. The position of the stimuli cannot be a criterion; only the four already mentioned can be (triangle, square, white, black). Your task is to find the right criterion within two trials, to tell me, when I will ask you, at the end of each serie (that is after the 2nd trial), which criterion is your response, and to tell me if your confidence is High or Low that you have found the correct criterion. If you don't know the answer tell me also. The interval between trials and problems is approximately the same, that is about 5 to 6 sec. You will win .05¢ each time you will have found the correct criterion and lose .02¢ each time you wont.

One last thing. I ask you to tell me when you will have decided of the way you will deal with the problem(s), and to describe your strategy to me. If you change your strategy during the experiment, tell me also. GOOD LUCK.

## GENERAL INSTRUCTIONS FRENCH

Cette expérience vise à étudier les ondes cérébrales associées à la réception d'un feedback. Elle sera divisée en deux parties: une période de pratique et une d'expérimentation.

### PRATIQUE

Cette partie est pour vous familiariser avec la procédure: distinguer le feedback positif du feedback négatif (stimulis auditifs), vous familiariser avec la boîte de réponse et apprendre quand clignoter des yeux (le clignotement influence les ondes cérébrales, ce qu'il faut donc contrôler).

Vous entendrez d'abord un son à travers les écouteurs. De 0.4 à 0.9 sec plus tard une image complexe sans signification vous sera présentée sur l'écran de TV. Un point blanc est fixé au centre de l'écran; je vous demande de le fixer au cours de l'expérience. A partir du moment où l'image apparaît sur l'écran, vous avez 1 sec pour presser sur un des boutons de la boîte de réponse (le blanc ou le rouge, n'importe lequel pour cette période de pratique). Si vous ne répondez pas à temps, une note apparaîtra au bas de l'écran ("Vas-y", "Let's go"). Si vous répondez à temps, vous entendrez alors un deuxième son, le feedback (ne veut rien dire pour cette période de pratique). Dans l'expérience, un son bas vous indique un choix "correct"; le son élevé vous indique un choix "incorrect". Ce feedback vous sera donné à un temps fixe après l'apparition de l'image sur l'écran, soit 2.1 sec. Vous ne devez pas clignoter des yeux à partir du moment où le premier son vous est présenté jusqu'à environ 5 sec après que vous aurez entendu le feedback. Je vous donnerai autant d'essais pratiques que nécessaire pour y arriver. Vous verrez à la fin vous déciderez du moment où je vous présenterai un essai en fixant des yeux après avoir clignoté entre les essais (ce que je peux suivre sur votre tracé EEG en dehors de la salle). Essayez de clignoter par petits coups plutôt que de fermer les yeux pour un temps lorsque vous sentez le besoin de clignoter.

INSTRUCTIONS FOR CONTROL GROUP  
FRENCH

Nous entrons maintenant dans l'expérimentation proprement dite. Le "timing" est exactement le même, les boutons (blanc et rouge) et les feedback aussi. Il faut également que vous fixiez le point au centre de l'écran. C'est la tâche qui change.

A chaque essai, maintenant, deux stimuli apparaîtront sur l'écran, alignés horizontalement. Toujours, un des stimuli sera un carré, l'autre un triangle, leur position étant au hasard. Tantôt ce sera le triangle qui sera blanc et le carré noir, tantôt ce sera l'inverse.

Des séries de deux essais vous seront présentés. A chaque essai un de ces stimuli est "correct" en ce sens que cela fut déterminé ainsi au hasard. Chaque essai contient quatre critères (triangle, carré, blanc, noir) et c'est au hasard qu'il a été déterminé que l'un ou l'autre de ceux-ci serait correct à chaque essai. Après chaque essai je veux que vous me disiez lequel des deux stimuli vous pensez est "correct" (le bouton de droite correspond au stimulus de droite et celui de gauche à celui de gauche). Utilisez l'index et le majeur de la main droite pour répondre. La nature du feedback que vous recevrez vous indiquera si votre choix est correct ou non. Les essais vous seront présentés en groupe de deux. Rappelez-vous toutefois que ces deux essais sont absolument indépendants l'un de l'autre. Votre tâche consiste donc à deviner à chaque essai quel stimulus contient le critère "correct". Je vous demanderai également de me dire tous les deux essais quels feedback vous avez reçus à ces deux essais et de me dire si vous êtes peu ou très confiant de vous rappelez correctement de la nature de ces feedback. L'intervalle entre chacun des essais sera toujours approximativement le même, soit 5 à 6 sec. Vous gagnerez .05¢ chaque fois que vous vous souviendrez des feedback reçus. Vous perdrez .02¢ chaque fois que vous l'aurez oublié. BONNE CHANCE.

INSTRUCTIONS FOR EXPERIMENTAL GROUP  
FRENCH

Nous entrons maintenant dans l'expérimentation proprement dite. Le "timing" est exactement le même, les boutons (blanc et rouge) et les feedback aussi. Il faut également que vous fixiez le point au centre de l'écran. C'est la tâche qui change.

A chaque essai, maintenant, deux stimuli apparaîtront sur l'écran, alignés horizontalement. Toujours, un des stimuli sera un carré, l'autre un triangle, leur position étant au hasard. Tantôt ce sera le triangle qui sera blanc et le carré noir, tantôt ce sera l'inverse.

Des séries de deux essais vous seront présentées, chacune de ces séries constituant un problème. Pour chaque problème ou série, un de ces stimuli est correct en ce sens que cela fut décidé ainsi de façon prédéterminée. Après chaque essai je veux que vous me disiez, en pressant sur un des boutons, lequel de ces deux stimuli vous pensez est correct (le bouton de droite correspond au stimulus de droite, celui de gauche au stimulus de gauche). Utilisez l'index et le majeur de la main droite pour répondre. La nature du feedback que vous recevrez vous indiquera si votre choix est correct. Il en sera ainsi pour les deux essais de sorte que vous pourrez apprendre sur quel critère (triangle, carré, blanc, noir) je me base pour vous dire que vous êtes correct. Le critère est toujours unique en ce sens qu'il n'y a pas de réponse "triangle blanc" par exemple. La position des stimuli n'est pas un critère. Il n'y en a que quatre (triangle, carré, blanc, noir). Votre tâche est de trouver ce critère en deux essais, de me dire, lorsque je vous le demanderai, à la fin de chaque série (c'est-à-dire après le 2<sup>ème</sup> essai) quel critère est votre réponse, et de me dire si vous êtes peu ou très confiant que votre choix est correct. Si vous ne connaissez pas la réponse dites-le moi aussi. L'intervalle entre les essais et les séries sera approximativement le même, soit de 5 à 6 sec. Vous gagnerez .05¢ chaque fois que vous trouverez le critère et perdrez .02¢ chaque fois que vous en l'aurez pas trouvé.

Une dernière chose, je vous demanderais de me dire quand vous aurez décidé de la façon dont vous allez résoudre les problèmes, et de me décrire votre stratégie. Si vous changez de stratégie en cours de route, vous me le direz aussi. BONNE CHANCE.

APPENDIX 4

POST QUESTIONNAIRE

CONTROL GROUP

## POST QUESTIONNAIRE - CONTROL GROUP


Did you try to find a pattern at the reception of Positive or Negative FB?

YES:

NO:

Did a Positive FB have an influence on your next response?

Explain.



Did a Negative FB have an influence on your next response?

Explain.

APPENDIX 5

Original Means and Standard Deviation for all Dependent  
Measurements According to Group (Experimental and Control) Feedback  
(Positive and Negative), Trial (First & Second) and Cortical Scalp Locations

CONTROL  
FIRST TRIAL  
FB Positive

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	1.0	1.5	.8	-.1	1.6	1.1
	SD	2.4	1.75	3.0	3.4	1.9	2.0
N <sub>1</sub>	M	-7.9	-.09	-6.7	-7.8	-3.1	-3.5
	SD	5.0	1.9	4.6	5.3	2.6	3.9
P <sub>3</sub>	M	8.4	5.5	4.4	3.2	10.5	10.3
	SD	5.4	2.3	5.0	4.8	3.8	3.6
P <sub>4</sub>	M	4.0	5.6	0.2	-0.7	8.0	7.4
	SD	3.1	2.0	5.4	4.0	3.4	3.4
LP 800	M	1.9	2.0	0.1	-0.4	3.5	2.9
	SD	3.4	2.5	3.8	3.9	2.1	3.0
LP 1000	M	1.7	1.9	0.9	0.3	3.0	2.4
	SD	3.9	2.5	3.4	3.7	2.7	2.3
LP 1800	M	1.5	1.0	2.0	0.9	1.9	1.5
	SD	4.3	3.4	4.3	5.0	3.1	2.9
FN 400	M	2.7	3.4	-2.3	-3.3	5.4	5.2
	SD	4.0	2.1	5.0	4.5	3.6	3.9
FN 600	M	.01	2.2	-2.2	-3.3	3.3	3.1
	SD	3.1	2.5	4.4	3.9	2.1	4.3

\* Dependent measurements are defined in the Methodological section p. 20-21.

CONTROL  
FIRST TRIAL  
FB Negative

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	-0.3	-0.2	0.1	-0.5	0.8	0.0
	SD	2.0	1.5	2.1	1.7	1.8	1.1
N <sub>1</sub>	M	-9.2	-1.9	-8.4	-9.2	-4.3	-4.6
	SD	3.6	1.9	5.0	5.6	3.4	4.0
P <sub>3</sub>	M	6.4	4.6	3.6	1.9	8.6	8.6
	SD	4.4	2.7	5.3	3.6	4.3	4.1
P <sub>4</sub>	M	3.2	4.5	0.9	-0.4	7.1	6.0
	SD	3.5	2.8	3.6	2.2	2.3	3.1
LP <sub>800</sub>	M	1.2	1.4	-0.04	-1.1	3.3	2.1
	SD	2.0	1.9	2.9	3.6	2.0	2.1
LP <sub>1000</sub>	M	0.8	0.7	0.5	-0.5	2.1	1.5
	SD	2.3	2.5	3.2	2.7	2.1	1.9
LP <sub>1800</sub>	M	-0.3	-0.9	0.6	-0.2	0.9	-0.01
	SD	2.5	2.5	3.3	3.8	2.2	2.3
FN <sub>400</sub>	M	-0.1	2.1	-3.2	-3.8	3.2	3.5
	SD	2.8	2.7	3.1	2.5	2.9	4.0
FN <sub>600</sub>	M	-1.5	1.4	-3.2	-4.5	2.9	1.7
	SD	2.5	2.3	3.8	3.6	1.0	3.1

\* Dependent measurements are defined in the Methodological section p. 20-21.

CONTROL  
SECOND TRIAL  
FB Positive

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	1.7	0.8	1.3	0.9	1.7	1.6
	SD	3.1	1.5	2.0	1.9	1.9	1.5
N <sub>1</sub>	M	-7.4	-1.3	-5.8	-6.4	-2.5	-4.0
	SD	5.2	1.8	3.4	5.9	4.2	4.2
P <sub>3</sub>	M	12.3	8.1	6.9	5.6	12.7	12.7
	SD	8.3	4.1	6.2	4.9	4.9	5.0
P <sub>4</sub>	M	5.1	5.8	1.5	1.7	8.7	8.2
	SD	5.2	2.9	4.4	3.8	4.0	4.0
LP <sub>800</sub>	M	4.0	3.1	1.9	2.2	5.2	4.0
	SD	3.1	2.7	2.9	2.5	2.3	2.3
LP <sub>1000</sub>	M	4.0	2.5	3.1	3.4	4.4	3.6
	SD	2.9	2.3	2.4	2.7	1.5	1.8
LP <sub>1800</sub>	M	5.6	1.9	4.8	5.2	4.0	3.5
	SD	2.8	2.9	2.9	3.7	1.5	2.1
FN <sub>400</sub>	M	3.2	3.6	-1.5	-1.9	6.3	5.5
	SD	5.9	3.1	4.9	3.6	4.8	4.8
FN <sub>600</sub>	M	2.1	3.1	-1.3	-0.9	5.3	4.2
	SD	4.5	1.9	4.2	3.7	3.6	3.4

\* Dependent measurements are defined in the Methodological section p. 20-21.

CONTROL  
SECOND TRIAL  
FB Negative

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	1.5	0.8	0.8	0.5	1.5	1.2
	SD	2.5	2.0	1.9	2.0	2.0	1.9
N <sub>1</sub>	M	-8.7	-0.7	-7.6	-8.6	-3.6	-4.0
	SD	3.2	1.3	3.6	4.2	2.2	2.8
P <sub>3</sub>	M	11.4	8.0	7.0	6.0	12.0	11.9
	SD	6.0	3.3	5.6	4.6	4.2	4.9
P <sub>4</sub>	M	5.3	6.8	2.7	2.4	10.0	8.0
	SD	3.4	2.9	2.7	2.3	3.1	3.4
LP 800	M	3.0	3.9	1.1	1.1	5.4	4.1
	SD	2.4	2.7	2.7	3.3	2.8	2.5
LP 1000	M	3.2	3.5	1.9	1.8	4.8	3.6
	SD	2.1	2.1	2.1	3.1	1.7	1.4
LP 1800	M	4.5	2.5	3.7	3.8	4.0	3.4
	SD	1.5	1.9	2.3	3.1	1.7	1.4
FN 400	M	2.5	4.7	-1.4	-1.6	6.0	5.8
	SD	4.2	2.7	2.7	2.5	3.4	3.6
FN 600	M	2.0	4.1	-2.0	-1.7	5.2	4.0
	SD	2.7	1.9	2.9	3.7	1.9	2.0

\* Dependent measurements are defined in the Methodological section p. 20-21.

EXPERIMENTAL  
FIRST TRIAL  
FB Positive

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	1.3	0.5	0.6	0.7	1.1	0.8
	SD	1.7	0.94	1.5	1.9	1.5	1.0
N <sub>1</sub>	M	-7.9	-2.1	-7.0	-6.6	-5.0	-4.6
	SD	3.9	1.6	3.1	4.6	3.1	2.6
P <sub>3</sub>	M	6.5	6.3	2.3	3.1	7.4	7.6
	SD	3.6	2.8	4.0	3.9	2.7	3.3
P <sub>4</sub>	M	2.9	5.8	-1.1	-1.9	6.4	5.4
	SD	3.1	3.1	2.7	3.7	2.5	2.6
LP <sub>800</sub>	M	1.7	2.2	0.2	-0.8	3.3	2.1
	SD	3.1	2.5	2.5	3.1	1.8	2.5
LP <sub>1000</sub>	M	1.7	2.1	1.3	0.9	3.0	1.9
	SD	2.8	3.2	2.9	2.9	2.3	2.5
LP <sub>1800</sub>	M	1.2	1.5	1.2	1.3	1.6	1.2
	SD	4.6	2.7	3.1	4.2	2.2	2.6
FN <sub>400</sub>	M	1.5	4.1	-4.2	-5.6	4.2	3.8
	SD	3.5	2.4	4.6	5.5	2.3	3.4
FN <sub>600</sub>	M	0.1	3.3	-3.7	-4.8	3.1	3.0
	SD	4.0	2.7	3.5	4.3	3.1	3.8

\* Dependent measurements are defined in the Methodological section p. 20-21.

EXPERIMENTAL  
FIRST TRIAL  
FB Negative

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	1.3	0.3	1.3	1.8	1.1	0.9
	SD	1.9	1.1	1.1	1.5	2.2	1.9
N <sub>1</sub>	M	-8.1	-1.4	-6.8	-6.0	-3.8	-3.1
	SD	5.4	2.9	4.4	5.2	3.8	3.8
P <sub>3</sub>	M	6.8	5.4	4.2	4.9	7.4	7.8
	SD	3.8	2.9	3.0	3.3	2.5	2.9
P <sub>4</sub>	M	3.2	5.2	0.7	-0.3	6.6	5.6
	SD	4.1	2.7	4.0	5.0	2.0	3.0
LP 800	M	1.7	3.2	1.7	0.9	4.4	3.3
	SD	3.2	2.9	3.2	4.0	2.7	2.5
LP 1000	M	2.5	3.1	2.9	3.1	4.2	3.3
	SD	3.8	4.0	3.6	5.2	3.4	3.1
LP 1800	M	1.4	2.3	2.3	3.6	1.7	1.7
	SD	3.8	3.2	3.1	4.2	2.5	2.8
FN 400	M	0.6	2.8	-4.2	-4.2	3.8	2.7
	SD	3.3	3.0	2.1	2.7	2.7	3.4
FN 600	M	0.1	3.4	-3.1	-3.8	3.6	2.2
	SD	3.4	2.1	3.4	3.6	2.5	3.0

\* Dependent measurements are defined in the Methodological section p. 20-21.

EXPERIMENTAL  
SECOND TRIAL  
FB Positive

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	0.4	-0.6	-0.1	-0.7	0.4	0.2
	SD	2.4	1.9	2.1	2.5	1.7	2.3
N1	M	-9.2	-2.9	-8.4	-9.2	-5.2	-4.8
	SD	3.6	3.4	3.0	2.9	3.4	3.2
P3	M	10.9	7.0	4.8	3.6	11.5	10.9
	SD	5.7	4.3	2.2	4.3	4.2	5.0
P4	M	4.6	4.9	-0.2	-1.5	7.6	6.1
	SD	3.6	2.7	2.0	2.7	2.6	3.0
LP 800	M	4.0	1.9	1.5	0.3	5.1	3.1
	SD	2.9	2.5	2.5	3.5	2.9	2.9
LP 1000	M	4.4	2.4	1.9	1.5	4.7	3.4
	SD	3.6	2.3	3.6	2.5	2.8	2.7
LP 1800	M	5.4	3.2	3.9	3.3	5.3	4.4
	SD	4.5	2.7	4.0	1.7	2.2	2.5
FN 400	M	1.3	3.4	-4.8	-5.4	4.5	3.7
	SD	4.4	4.1	3.6	3.0	2.9	4.2
FN 600	M	2.2	2.4	-3.1	-3.8	4.5	2.8
	SD	3.6	2.9	2.1	2.6	3.1	3.6

\* Dependent measurements are defined in the Methodological section p. 20-21.

EXPERIMENTAL  
SECOND TRIAL  
FB Negative

Dependent Measurements*		CZ	OZ	F3	F4	P3	P4
CNV	M	1.6	-0.1	1.1	0.9	1.6	1.1
	SD	1.9	1.1	1.6	1.9	1.5	1.8
N1	M	-8.1	-1.8	-7.1	-8.0	-3.4	-3.4
	SD	4.9	1.4	3.5	3.8	3.0	1.6
P3	M	9.5	7.0	4.6	2.7	10.6	10.2
	SD	5.5	3.4	3.7	2.7	3.4	4.1
P4	M	6.2	6.3	1.7	0.3	9.8	8.0
	SD	4.3	3.2	3.2	2.2	3.6	3.0
LP 800	M	4.4	3.4	3.2	2.4	6.0	4.2
	SD	3.1	2.7	2.6	1.9	3.1	2.3
LP 1000	M	4.2	2.5	3.7	3.7	5.3	4.0
	SD	3.3	2.3	3.3	2.0	2.6	2.0
LP 1800	M	5.3	2.6	4.2	3.8	4.6	3.9
	SD	4.4	3.1	3.8	2.3	2.5	2.5
FN 400	M	2.5	4.6	-3.4	-4.1	6.4	4.8
	SD	4.2	2.4	2.8	2.1	3.9	3.8
FN 600	M	2.8	4.3	-0.5	-2.1	6.5	5.0
	SD	3.4	3.4	2.6	2.0	3.6	3.5

\* Dependent measurements are defined in the Methodological section p. 20-21.

APPENDIX 6

Revised Means for all Dependent Measurements According to  
Their Scalp Distribution for Each Trial (First & Second)  
Across Group (Experimental and Control) and Feedback (Positive and Negative)

F3 F4  
 CZ  
 P3 P4  
 OZ

## FIRST TRIAL

	EXPERIMENTAL				CONTROL			
	FB+		FB-		FB+		FB-	
N <sub>1</sub>	-7.6	-7.3	-8.1	-7.8	-7.5	-7.7	-8.5	-8.7
	-9.2		-9.4		-8.9		-8.9	
	-6.1	-5.4	-4.9	-4.0	-4.7	-4.6	-5.1	-4.6
	-2.6		-1.7		-1.4		-1.7	
P <sub>3</sub>	1.7	2.4	2.9	3.1	3.6	3.3	3.5	2.4
	5.2		5.5		7.4		6.7	
	6.3	6.8	6.3	6.9	8.9	9.2	7.8	8.6
	5.8		5.1		5.0		4.8	
P <sub>4</sub>	-1.7	-2.6	-0.6	-2.1	-0.6	-0.6	0.8	0.1
	1.6		1.9		3		3.5	
	5.3	4.6	5.5	4.7	6.4	6.3	6.3	6.0
	5.3		4.9		5.1		4.7	
LP 800	-0.4	-1.5	0.4	-0.9	-0.7	-0.3	-0.1	-0.6
	0.4		0.4		0.9		1.5	
	2.2	1.3	3.3	2.4	1.9	1.8	2.5	2.1
	1.7		2.9		1.5		1.6	
LP 1000	0.7	0.2	1.6	1.3	0.1	0.4	0.4	0
	0.4		1.2		0.7		1.1	
	1.9	1.1	3.1	2.4	1.4	1.3	1.3	1.5
	1.6		2.8		1.4		0.9	
LP 1800	0.6	0.6	1.0	1.8	1.2	1.0	0.5	0.3
	-0.1		0.1		0.5		0	
	0.5	0.4	0.6	0.8	0.3	0.4	0.1	0
	1.0		2.0		0.5		-0.7	

F3 F4  
 CZ  
 P3 P4  
 OZ

FIRST TRIAL (cont'd)

	EXPERIMENTAL				CONTROL			
	FB+		FB-		FB+		FB-	
FN 400	-4.8	-6.3	-5.5	-6.0	-3.1	-3.2	-3.3	-3.3
	0.2		-0.7		1.7		0.2	
	3.1	3.0	2.7	1.8	3.8	4.1	2.4	3.5
	3.6		2.5		2.9		2.3	
FN 600	-4.3	-5.5	-4.4	-5.6	-3.0	-3.2	-3.3	-4
	-1.2		-1.2		-1.0		-1.2	
	2.0	2.2	2.5	1.3	1.7	2.0	2.1	1.7
	2.8		3.1		1.7		1.6	

F3      F4  
 CZ  
 P3      P4  
 OZ

SECOND TRIAL

	EXPERIMENTAL				CONTROL			
	FB+		FB-		FB+		FB-	
N1	-8.3	-8.5	-8.2	-8.9	-7.1	-7.3	-8.4	-9.1
		-9.6		-9.7		-9.1		-10.2
	-5.6	-5.0	-5.0	-4.5	-4.2	-5.6	-5.1	-5.2
		-2.3		-1.7		-2.1		-1.5
P3	4.9	4.3	3.5	1.8	5.6	4.7	6.2	5.5
		10.5		7.9		10.6		9.9
	11.1	10.7	9	9.1	11.0	11.1	10.5	10.7
		7.6		7.1		7.3		7.2
P4	-0.1	-0.8	0.6	-0.6	0.2	0.8	1.9	1.9
		4.2		4.6		3.4		3.8
	7.2	5.9	8.2	6.9	7.0	6.6	8.5	6.8
		5.5		6.4		5.0		6.0
LP 800	1.6	1.0	2.1	1.5	0.6	1.3	0.3	0.6
		3.6		2.8		2.3		1.5
	4.7	2.9	4.4	3.1	3.5	2.4	3.9	2.9
		2.5		3.5		2.3		3.1
LP 1000	2.0	2.2	2.6	2.8	1.8	2.5	1.1	1.3
		4.0		2.6		2.3		1.7
	4.3	3.2	3.7	2.9	2.7	2.0	3.3	2.4
		3.0		2.6		1.7		2.7
LP 1800	4.0	4.0	3.1	2.9	3.5	4.3	2.9	3.3
		5.0		3.7		3.9		3.0
	4.9	4.2	3.0	2.8	2.3	1.9	2.5	2.2
		3.8		2.7		1.1		1.7

F3      F4  
 CZ  
 P3      P4  
 OZ

## SECOND TRIAL (cont'd)

	EXPERIMENTAL				CONTROL			
	FB+		FB-		FB+		FB-	
FN 400	-4.7	-4.7	-4.5	-5.0	-2.8	-2.8	-2.2	-2.1
	0.9		0.9		1.5		1.0	
	4.1	3.5	4.8	3.7	4.6	3.9	4.5	4.6
	4.0		4.7		2.8		3.9	
FN 600	-3.0	-3.1	-1.6	-3.0	-2.6	-1.8	-2.8	-2.2
	1.8		1.2		0.4		0.5	
	4.1	2.6	4.9	3.9	3.6	2.6	3.7	2.8
	3.0		4.4		2.3		3.3	

APPENDIX 7

SIGNIFICANT F TABLES FOUND AT EACH ELECTRODE AREA

WITHIN SECOND  
FB X GROUP

CZ

Dependent Variable*	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G ERROR	.2250.0 238976.0	.2250.0 13276.4	0.17	0.69
	FB INT ERROR	6150.4 2131.6 23268.0	6150.4 2131.6 1292.7	4.76 1.65	0.043* 0.22
LP 1000	G ERROR	3591.0 55445.5	3591.0 3080.3	1.17	0.29
	FB INT ERROR	2576.0 354.0 4839.5	2576.0 354.0 268.9	9.58 1.32	0.006* 0.27
LP 1800	G ERROR	1612.9 68488.6	1612.9 3802.9	0.42	0.52
	FB INT ERROR	2890.0 102.4 10603.6	2890.0 102.4 589.1	4.91 0.17	0.04* 0.68

\*Degrees of freedom for all F tables are 1 for the numerator and 18 for the denominator.

WITHIN SECOND  
GROUP X FB

F4

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P3	G	9211.2	9211.2	1.42	0.25
	ERROR	116507.1	6472.6		
	FB	1311.0	1311.0	1.01	0.33
	INT	6027.0	6027.0	4.63	0.045*
	ERROR	23406.5	1300.4		

WITHIN SECOND  
GROUP X FB

P3

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	1232.1	1232.1	0.18	0.67
	ERROR	121899.8	6772.2		
	FB	3168.4	3168.4	6.70	0.019*
	INT	1742.4	1742.4	3.68	0.07
	ERROR	8513.2	473.0		
LP 1800	G	5808.1	5808.1	2.27	0.15
	ERROR	46079.4	2560.0		
	FB	1254.4	1254.4	4.11	0.06
	INT	2496.4	2496.4	8.19	0.01*
	ERROR	5489.2	305.0		

WITHIN SECOND  
GROUP X FB

P4

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
LP 1800	G	6250.0	6250.0	3.20	0.09
	ERROR	35206.1	1955.9		
	FB	1144.9	1144.9	2.31	0.15
	INT	2433.6	2433.6	4.91	0.039*
	ERROR	8924.5	495.8		

WITHIN SECOND  
GROUP X FB

02

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
LP 800	G	220.9	220.9	0.08	0.77
	ERROR	47029.0	2612.7		
	FB	1612.9	1612.9	5.42	0.031*
	INT	4.9	4.9	0.02	0.90
	ERROR	5358.2	297.7		

WITHIN FB+  
GROUP X TRIAL

CZ

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	2772.2	2772.2	0.31	0.58
	ERROR	159736.1	8874.2		
	TRIAL	39250.2	39250.2	13.98	0.001*
	INT	2640.6	2640.6	0.94	0.35
	ERROR	50537.7	2807.6		
P <sub>4</sub>	G	172.2	172.2	0.04	0.84
	ERROR	71324.1	3962.4		
	TRIAL	4818.1	4818.0	4.80	0.042*
	INT	2325.6	2325.6	2.32	0.15
	ERROR	18073.9	1004.1		
LP 800	G	462.4	462.4	0.24	0.63
	ERROR	35291.7	1960.7		
	TRIAL	11628.1	11628.1	10.87	0.004*
	INT	1638.4	1638.4	1.53	0.23
	ERROR	19256.5	1069.8		
LP 1000	G	1243.2	1243.2	0.52	0.48
	ERROR	43430.1	2412.8		
	TRIAL	15327.2	15327.2	9.81	0.006*
	INT	1890.6	1890.6	1.21	0.29
	ERROR	28120.7	1562.3		

WITHIN FB+  
GROUP X TRIAL

CZ (cont'd)

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
LP 1800	G	164.0	164.0	0.04	0.84
	ERROR	74225.3	4123.6		
	TRIAL	40768.2	40768.2	15.93	0.001*
FN 600	INT	1404.2	1404.2	0.55	0.47
	ERROR	46072.1	2559.6		
	G	970.2	970.2	0.21	0.65
FN 600	ERROR	84536.1	4696.4		
	TRIAL	10465.2	10465.2	9.52	0.006*
	INT	1334.0	1334.0	1.21	0.29
FN 600	ERROR	19795.1	1099.7		

WITHIN FB+  
GROUP X TRIAL

F3

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	3980.0	3980.0	0.58	0.45
	ERROR	122585.9	6810.3		
	TRIAL	14250.6	14250.6	7.84	0.012*
	INT	748.2	748.2	0.41	0.53
	ERROR	32732.7	1818.5		
LP 800	G	950.6	950.6	0.61	0.45
	ERROR	28093.9	1560.8		
	TRIAL	5546.0	5546.0	8.44	0.009*
	INT	235.2	235.2	0.36	0.56
	ERROR	11827.3	657.1		
LP 1000	G	220.9	220.9	0.08	0.79
	ERROR	52340.5	2907.8		
	TRIAL	5017.6	5017.6	5.73	0.028*
	INT	122.5	122.5	0.14	0.71
	ERROR	15756.9	875.4		
LP 1800	G	14.4	14.4	0.00	0.95
	ERROR	74636.6	4146.5		
	TRIAL	17640.0	17640.0	11.28	0.004*
	INT	547.6	547.6	0.35	0.56
	ERROR	28153.4	1564.1		

WITHIN FB+  
GROUP X TRIAL

F4

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P4	G	7209.2	7209.2	2.13	0.1621
	ERROR	61049.1	3391.6		
	TRIAL	5593.2	5593.2	7.64	0.013*
	INT	55.2	55.2	0.08	0.79
	ERROR	13182.1	732.3		
LP 800	G	1177.2	1177.2	0.77	0.39
	ERROR	27656.1	1536.4		
	TRIAL	8850.6	8850.6	13.51	0.002*
	INT	497.0	497.0	0.76	0.40
	ERROR	11792.9	655.2		
LP 1000	G	65.0	65.0	0.05	0.82
	ERROR	23150.5	1286.1		
	TRIAL	9272.0	9272.0	12.54	0.002*
	INT	4.2	4.2	0.01	0.94
	ERROR	13309.3	739.4		
LP 1800	G	216.2	216.2	0.07	0.80
	ERROR	58229.1	3234.9		
	TRIAL	23571.0	23571.0	19.19	0.000*
	INT	11.0	11.0	0.01	0.93
	ERROR	22108.5	1228.2		

WITHIN FB+  
GROUP X TRIAL

F4 (cont'd)

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
FN 600	G	7075.6	7075.6	1.93	0.18
	ERROR	66059.8	3670.0		
	TRIAL	7398.4	7398.4	7.63	0.013*
	INT	774.4	774.4	0.80	0.38
	ERROR	17448.2	969.3		

WITHIN FB+  
GROUP X TRIAL

P3

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	2975.6	2975.6	0.61	0.45
	ERROR	87814.9	4878.6		
	TRIAL	26471.0	26471.0	18.12	0.000*
	INT	3744.2	3744.2	2.56	0.13
	ERROR	26291.3	1460.6		
P <sub>4</sub>	G	435.6	435.6	0.1	0.76
	ERROR	80832.3	4490.6		
	TRIAL	3610.0	3610.0	7.68	0.013*
	INT	1232.1	1232.1	2.62	0.12
	ERROR	8463.9	470.22		
LP 800	G	1288.2	1288.2	0.53	0.48
	ERROR	43735.1	2429.7		
	TRIAL	9030.0	9030.0	15.87	0.001*
	INT	455.6	455.6	0.8	0.38
	ERROR	10238.9	568.8		
LP 1000	G	2689.6	2689.6	1.06	0.32
	ERROR	45690.5	2538.3		
	TRIAL	7840.0	7840.0	8.78	0.009*
	INT	532.9	532.9	0.6	0.45
	ERROR	16074.1	893.0		

WITHIN FB+  
GROUP X TRIAL

P3 (cont'd)

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
LP 1800	G	4818.0	4818.0	2.13	0.16
	ERROR	40637.3	2257.6		
	TRIAL	21949.2	21949.2	15.86	0.00*
	INT	3222.0	3222.0	2.33	0.14
	ERROR	24907.3	1383.7		
FN 600	G	442.2	442.2	0.12	0.73
	ERROR	66812.2	3711.8		
	TRIAL	9030.0	9030.0	8.0	0.011*
	INT	5.63	5.63	0.00	0.94
	ERROR	20259.8	1125.5		

WITHIN FB+  
GROUP X TRIAL

P4

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	2560.0	2560.0	0.41	0.53
	ERROR	111716.0	6206.4		
	TRIAL	21902.4	21902.4	12.89	0.002*
	INT	2822.4	2822.4	1.66	0.21
	ERROR	30589.2	1699.4		
P <sub>4</sub>	G	1946.0	1946.0	0.46	0.5
	ERROR	76323.2	4240.1		
	TRIAL	2673.2	2673.2	4.45	0.049*
	INT	1113.02	1113.02	1.85	0.19
	ERROR	10820.2	601.1		
LP <sub>800</sub>	G	265.2	265.2	0.1	0.76
	ERROR	49609.2	2756.1		
	TRIAL	4020.0	4020.0	6.88	0.017*
	INT	1092.0	1092.0	1.87	0.19
	ERROR	10514.4	584.14		
LP <sub>1000</sub>	G	1188.1	1188.1	0.61	0.44
	ERROR	34821.0	1934.5		
	TRIAL	5760.0	5760.0	7.95	0.011*
	INT	1440.0	1440.0	1.99	0.17
	ERROR	13044.0	724.6		

WITHIN FB+  
GROUP X TRIAL

P4 (cont'd)

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
LP 1800	G	4161.6	4161.6	2.02	0.17
	ERROR	37167.8	2064.8		
	TRIAL	17977.6	17977.6	12.04	0.003*
	INT	4080.4	4080.4	2.73	0.11
	ERROR	26869.0	1492.7		

WITHIN FB+  
GROUP X TRIAL

OZ

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	756.9	756.9	0.23	0.64
	ERROR	59268.2	3292.7		
	TRIAL	8820.9	8820.9	6.64	0.019*
	INT	168.1	168.1	0.13	0.73
	ERROR	23911.0	1328.4		
LP 1800	G	6076.2	6076.2	2.13	0.16
	ERROR	51408.1	2856.0		
	TRIAL	5929.2	5929.2	6.70	0.019*
	INT	2640.6	2640.6	2.98	0.10
	ERROR	15932.7	885.1		

WITHIN FB-  
GROUP X TRIAL

CZ

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	5978.0	5978.0	0.57	0.46
	ERROR	189305.9	10516.9		
	TRIAL	18020.0	18020.0	13.33	0.002*
	INT	265.2	265.2	0.2	0.66
	ERROR	24328.2	1351.5		
LP 1800	G	308.0	308.0	0.17	0.69
	ERROR	33510.2	1861.6		
	TRIAL	24354.2	24354.2	12.95	0.002*
	INT	156.02	156.02	0.08	0.78
	ERROR	33850.2	1880.6		
FN 600	G	193.6	193.6	0.06	0.8
	ERROR	53716.3	2984.2		
	TRIAL	9859.6	9859.6	5.99	0.026*
	INT	372.1	372.1	0.22	0.64
	ERROR	30058.3	1669.9		

WITHIN FB-  
GROUP X TRIAL

F3

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
LP 1800	G	319.2	319.2	0.11	0.75
	ERROR	54517.6	3028.7		
	TRIAL	10208.0	10208.0	9.23	0.007*
	INT	55.2	55.2	0.05	0.83
	ERROR	19897.2	1105.4		
FN 400	G	11055.6	11055.6	4.45	0.049*
	ERROR	44669.9	2481.6		
	TRIAL	2002.2	2002.2	1.47	0.24
	INT	11.02	11.02	0.01	0.92
	ERROR	24453.2	1358.51		
FN 600	G	0.225	0.225	0.00	0.99
	ERROR	62241.6	3457.8		
	TRIAL	5688.2	5688.2	4.89	0.040*
	INT	2839.2	2839.2	2.44	0.13
	ERROR	20926.0	1162.5		

WITHIN FB-  
GROUP X TRIAL

F4

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	4774.2	4774.2	0.71	0.41
	ERROR	121600.0	6755.6		
	TRIAL	1974.0	1974.0	14.02	0.06
	INT	10923.0	10923.0	22.2	0.0002*
	ERROR	8849.45	491.64		
P <sub>4</sub>	G	11971.6	11971.6	6.11	0.023*
	ERROR	35316.3	1962.01		
	TRIAL	6502.6	6502.5	3.25	0.08
	INT	40.0	40.0	0.02	0.89
	ERROR	36063.5	2003.5		
LP 800	G	211.6	211.6	0.11	0.75
	ERROR	35087.9	1949.3		
	TRIAL	7398.4	7398.4	5.72	0.028*
	INT	688.9	688.9	0.53	0.47
	ERROR	23284.7	1293.6		
LP 1800	G	739.6	739.6	0.33	0.57
	ERROR	40751.3	2263.9		
	TRIAL	9120.4	9120.4	6.67	0.019*
	INT	2102.5	2102.5	1.54	0.23
	ERROR	24620.1	1367.8		

WITHIN FB-  
GROUP X TRIAL

F4 (cont'd)

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
FN 400	G	17347.2	17347.2	5.48	0.031*
	ERROR	56985.2	3165.8		
	TRIAL	2608.2	2608.2	3.52	0.08
	INT	30.6	30.6	0.04	0.84
	ERROR	13329.6	740.5		
FN 600	G	2975.6	2975.6	1.08	0.31
	ERROR	49589.6	2754.9		
	TRIAL	11055.6	11055.6	8.71	0.009*
	INT	265.2	265.2	0.21	0.65
	ERROR	22855.6	1269.7		

WITHIN FB-  
GROUP X TRIAL

P3

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P <sub>3</sub>	G	5593.2	5593.2	0.97	0.34
	ERROR	103794.0	5766.3		
	TRIAL	16120.2	16120.2	17.75	0.001*
	INT	4.2	4.22	0.00	0.95
	ERROR	16347.05	908.2		
P <sub>4</sub>	G	632.0	632.0	0.21	0.65
	ERROR	54232.4	3012.9		
	TRIAL	12709.2	12709.2	7.4	0.014*
	INT	81.2	81.2	0.05	0.83
	ERROR	30933.05	1718.5		
LP 1800	G	680.6	680.6	0.42	0.53
	ERROR	29154.8	1619.7		
	TRIAL	12780.6	12780.6	10.88	0.004*
	INT	0.02	0.02	0.00	0.99
	ERROR	21134.8	1174.1		
FN 400	G	240.1	240.1	0.06	0.8
	ERROR	67885.5	3771.4		
	TRIAL	9610.0	9610.0	10.31	0.005*
	INT	8.1	8.1	0.01	0.92
	ERROR	16779.9	932.2		
FN 600	G	1334.0	1334.0	0.68	0.42
	ERROR	35065.8	1948.1		
	TRIAL	8732.8	8732.03	8.32	0.009*
	INT	319.2	319.2	0.3	0.59
	ERROR	18889.2	1049.4		

WITHIN FB-  
GROUP X TRIAL

P4

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P3	G	6528.0	6528.0	0.98	0.34
	ERROR	120172.4	6676.2		
	TRIAL	10017.22	10017.22	17.47	0.014*
	INT	9.02	9.02	0.01	0.94
	ERROR	24124.3	1340.2		
P4	G	883.6	883.6	0.26	0.61
	ERROR	62306.8	3461.5		
	TRIAL	5017.6	5017.6	4.91	0.039*
	INT	1299.6	1299.6	1.27	0.27
	ERROR	18376.8	1020.9		
LP 1800	G	1199.0	1199.0	1.24	0.28
	ERROR	17413.8	967.4		
	TRIAL	9828.2	9828.2	8.31	0.009*
	INT	24.0	24.0	0.02	0.88
	ERROR	21298.2	1183.2		
FN 400	G	3841.6	3841.6	0.85	0.37
	ERROR	81625.4	4534.7		
	TRIAL	5198.4	5198.4	6.82	0.018*
	INT	462.4	452.4	0.61	0.45
	ERROR	13716.2	762.0		
FN 600	G	207.0	207.0	0.08	0.77
	ERROR	46256.2	2569.8		
	TRIAL	7535.03	7535.03	6.84	0.017*
	INT	1357.2	1375.2	1.23	0.28
	ERROR	19818.2	1101.01		

WITHIN FB-  
GROUP X TRIAL

OZ

Dependent Variable	Source	Sum of Squares	Mean Square	F	Prob.
P3	G	27.2	27.2	0.01	0.93
	ERROR	60564.6	3364.7		
	TRIAL	10989.2	10989.2	14.75	0.001*
	INT	42.02	42.02	0.06	0.81
	ERROR	13410.3	745.01		
LP 1800	G	7784.1	7784.1	4.91	0.039*
	ERROR	28534.5	1585.2		
	TRIAL	5522.5	5522.5	2.88	0.11
	INT	1587.6	1587.6	0.83	0.37
	ERROR	34504.9	1916.9		
FN 400	G	547.6	547.6	0.29	0.59
	ERROR	33899.9	1883.3		
	TRIAL	7896.1	7896.1	8.51	0.009*
	INT	250.0	250.0	0.27	0.61
	ERROR	16705.9	928.1		
FN 600	G	3960.1	3960.1	1.83	0.19
	ERROR	38937.5	2163.1		
	TRIAL	4884.1	4884.1	5.3	0.033*
	INT	48.4	48.4	0.05	0.82
	ERROR	16583.5	921.3		