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# THE EFFECTS OF ALCOHOL UPON HEMISPHERIC FUNCTIONAL ASYMMETRY IN MOTOR, SENSORY AND COGNITIVE TASKS

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# DEDICATION

This dissertation is dedicated to the four girls in my life:

Louise, René, Michelle, and Yvonne

whose love and understanding have made this accomplishment

both possible and worthwhile.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

## LIST OF ILLUSTRATIONS

# THE EFFECTS OF ALCOHOL UPON HEMISPHERIC FUNCTIONAL ASYMMETRY IN MOTOR, SENSORY AND COGNITIVE TASKS

## CHAPTER I

## LITERATURE REVIEW AND STATEMENT OF PROBLEM

The general purpose of this study is to examine the effects of low and moderate doses of ethyl alcohol upon brain function in man. More specifically, an attempt is made to evaluate the effects of alcohol with respect to (1) differences in functional asymmetry of the cerebral hemispheres and (2) the basic nature of the tasks used to sample central nervous system (CNS) functions: sensory (input), cognitive (information processing and decision making), and motor (output). The tasks used to assess these functions require divided or selective attention to stimuli which present similar, but not identical, information simultaneously to the two cerebral hemispheres.

### Functional Asymmetry and Cerebral Dominance

The issue of cerebral dominance has been lingering in the field of neurology for over a century, sometimes fostering new insight into brain function and in other cases hindering advances in this area. The main shift in thinking about cerebral dominance has been from the idea that one hemisphere is wholly dominant, exercising complete control over the other, to a more moderate position which states that dominance depends upon the kind of ability under consideration. In this light Benton (1970, p. 294) has recently defined cerebral dominance as ". . . a state of affairs in which one hemisphere possesses functional properties or subserves behavioral functions that are not shared by the other hemisphere, either at all or to the same degree." This position of functional asymmetry states that the right hemisphere is dominant for some functions while the left hemisphere is dominant for others.

Functional asymmetry has been a central issue in human neuropsychology throughout the past decade. Numerous studies have investigated the visual and auditory modalities as the most accessible routes through which to study brain function in the normal human. In the visual modality, research has centered around the technique of tachistoscopic recognition of verbal and non-verbal stimuli, as a function of left visual field (LVF) or right visual field (RVF) presentation. The auditory studies have capitalized on the technique of dichotic stimulation introduced by Broadbent (1958) in which different inputs are delivered to both ears simultaneously and one is asked to recall what he has heard.

## Visual Studies

When English words or letters are presented to one visual field (VF) at a time, they are more accurately perceived in the RVF. Several studies have attempted to explain this finding by relating it to eye movement patterns developed in reading (Mishkin and Forgays, 1952; Forgays, 1953; Orbach, 1953; Heron, 1957). Kimura (1961-1966), however, has suggested that it may be due in part to dominance for language functions generally attributed to the left hemisphere. Bryden (1960), following Kimura's 1959 work, conducted a study to find out more about how the perception of tachistoscopically presented geometric forms compared with the perception of letters. When he presented such forms to one VF at a time, he found the geometrical material was recognized equally well in both visual fields. In a later study (1965) he reported that right-handers were significantly more accurate in identifying letters presented in the RVF, while left-handers failed to show any consistent left-right field differences. He suggested that cerebral dominance may be at least partially responsible for these results.

Kimura (1966) studied recognition of letters and nonsense forms, as well as enumeration of letters, dots and meaningful forms. Her findings indicated better RVF recognition for both large and small letters, and enumeration of letters, no left-right differences for recognition of nonsense forms or nonsense form discrimination, and better LVF enumeration of dots and simple meaningful forms.

Hayashi and Bryden (1967) sought to relate these VF differences in perception to the visual sighting and acuity dominance of the observer. They performed two experiments to determine the relation of sighting and acuity dominance to tachistoscopic recognition. In each study single letters were exposed binocularly approximately $8^{\circ}$ to the right or left of fixation for a duration of 5 msec. longer than the subject's recognition threshold (as determined by prior testing). The first experiment failed to show any relationship between sighting dominance and visual field differences. The second study suggested that both visual acuity and cerebral dominance affect VF differences. While all of their subjects were "strongly right-handed," those who were right eye acuity dominant showed a large RVF superiority; whereas no VF differences in recognition were found in the left eye acuity dominant subjects. They suggested that the interaction between acuity dominance and cerebral dominance may be mediated by the relative superiority of the crossed optic pathway.

> This superiority would provide an advantage to the left visual field of the left eye and to the right visual field of the right eye. Taken in conjunction with the effects of acuity dominance and cerebral dominance, it would lead us to expect a large right field superiority in right acuity-dominant subjects for whom the right eye contributes the higher level of stimulation. (p. 611)

Following Hayashi and Bryden's reasoning, if the right hemisphere is indeed dominant for non-verbal visual-spatial organization, nonsense forms and possibly all stimuli not requiring linguistic analysis should be recognized better in the LVF of left eye acuity dominant subjects. The right eye acuity dominance coupled with the dominance of the left hemisphere for language functions seems to be a ready explanation for positive VF differences obtained for verbal materials as well as the lack of field differences found with so-called non-verbal stimuli. It should be emphasized that these suggestions are based on threshold recognition studies and may not be applicable to experimental conditions using definitely suprathreshold stimuli. This, however, is yet tc be investigated.

In each of the studies cited above, the subject was required to make a vocal naming response and was allowed whatever time was convenient to make such response. It is probable that some of the conflicting findings concerning non-verbal stimuli may be due to a confounding of recognition *per se* and the required oral naming response. When the corpus callosum is intact, most unilaterally presented stimuli have bilateral distribution via the callosum, allowing the two hemispheres to communicate with each other. In the case of non-verbal stimuli presented to the left hemisphere, the information may have to cross the callosum to the right hemisphere to be processed and then return via the callosum to the left hemisphere for the required verbal response. Therefore, the "recognition" experiments cannot isolate the hemisphere primarily responsible for processing the information. The use of a non-verbal response measure would appear to be a more valid procedure.

A clinical study by Levy, Trevarthen and Sperry (1972) examined hemispheric differences in visual perception of chimeric stimuli. These stimuli were tachistoscopically presented to patients whose cerebral hemispheres had been disconnected by commissurotomy. The subjects viewed the stimuli monocularly with their dominant eye for optimal vision. When stimuli were presented to the right hemisphere a manual hand-pointing response was necessitated, with left hemisphere stimulation, both the hand-pointing and a vocal naming response were tested. They found that when the task involves only a simple visual recognition, a visual encoding takes place, which is mediated by the right hemisphere and is based on the form properties of the stimulus instead of a separate feature analysis. However, when "some form of visual encoding is specifically required, the left hemisphere takes over and attempts a visual recognition based on nameable analytical features of the stimulus." (p. 75)

A review of the research on visual approaches to hemispheric functional asymmetry indicates that a RVF superiority is usually found for the perception of alphabetical material (Goodglass and Barton, 1963; Barton, Goodglass and Shai, 1965; Kimura, 1966; McKeever and Huling, 1970a, 1970b, 1971; Rubino, 1970; Hines and Satz, 1971; Hines, 1972; Fontenot, 1973) and of familair objects (Wyke and Ettlinger, 1961). A LVF superiority is found for facial recognition (Rizzolatti, Umilta, and Berlucchi, 1971; Geffen, Bradshaw and Wallace, 1971), as well as perceiving the location and enumeration of dots (Kimura, 1966) and discrimination of the slope of lines (Durnford and Kimura, 1971). Durnford and Kimura also demonstrated that the threshold for binocular depth perception was lower in the LVF than in the RVF, while Schell and Satz (1970) have found superior perception for non-verbal visual designs in the LVF. These LVF findings have their complement in clinical studies of patients with right hemisphere brain lesions. Such patients show greater impairment than patients with unilateral left hemisphere lesions in facial recognition (Benton and Van Allen, 1968; DeRenzi, Faglioni and Spinnler, 1968; Yin, 1970), in discriminating the slope and position of lines (Warringtion and Rabin, 1970), in stereopsis (Julesz, 1964; Carmon and Bechtoldt, 1969), and in the identification or interpretation of complex visual forms and non-verbal patterns (Kimura, 1963; Meier and French, 1965; Rubino, 1970). Spatial deficits are also seen in simple tactual tasks following posterior right hemisphere lesions (Carmon and Benton, 1969; Faglioni, Scotti and Spinnler, 1969; DeRenzi and Scotti, 1969), but comparisons with non-braindamaged subjects are not yet available.

At the electrophysiological level, hemispheric asymmetry has been studied by recording evoked potentials. Beck and Dustman (1970) have demonstrated marked hemispheric asymmetry in both amplitude and stability of the visual non-verbal evoked potential, with the evoked response being greater in the right hemisphere than in the left. If a speech stimulus is used, the electrocortical responses are larger in the left hemisphere than in the right (Morrell & Salamy, 1971).

Posner, (1967, 1969) has developed some interesting techniques for the investigation of the elementary processes involved in, and prior to,. the assigning of names to visual stimuli. Since almost all tachistoscopic recognition studies require the subject to give a vocal naming response, and since language processes are usually assumed to be a left hemisphere function, it appears that Posner's methods may have direct relevance to the study of hemispheric functional asymmetry.

His technique is unique in that it provides for the investigation of three levels of processing of the same physical stimulus. The technique requires the subject to classify a pair of letters as "same" or "different." The dependent variable is reaction time. At the simplest level of processing the response "same" is given when the two letters are physically identical (e.g., AA), at the next level when they have the same name (e.g., Aa), and at a third level when they are named by some given rule (both letters are vowels). Hence, the same stimulus-response combination may be studied at each of three levels of perceptual-cognitive processing.

Posner's results indicate that stimulus familiarity, or prior learning effects, does not affect the time required to make a physical identity match, since physically identical letters are not done faster than matching nonsense forms of similar complexity which the subject has never seen before. The suggestion that the physical identity match gets at the very early stages of the naming process is further supported by the finding that a letter appears to operate as a single unit at this level since it is no faster to match single line slants (//) than it is to match letters. The physical identity task required about 450-465 msec., with no significant differences in the time required for "same" and "different" responses.

Logically, the second level of processing, naming, requires the subject to first locate in stored information the appropriate names for the two possibly dissimilar stimuli (e.g., Aa), and then compare these recalled names to see if they match. This additional processing is reflected in the additional 70-100 msec. required to match stimulus names at the name identity level. Further, it appears that transforming the stimulus by changing its size, orientation, etc. has the effect of producing reaction times intermediate to those of physical identity and name identity. In Sternberg's (1969) terminology, this may be considered as injecting "noise" into the system, requiring a "cleaning-up" of the stimulus prior to response selection.

The third level of processing, which Posner calls rule identity, requires a higher level of analysis in which the match is made on the basis of membership in a given class of stimuli. This type of processing requires still more time than the name identity level.

Filby and Gazzaniga (1969) conducted two studies attempting to demonstrate differences in reaction time to the presence or absence of a tachistoscopically presented dot as a function of VF of presentation. When a voice response was required, a 40 msec. faster reaction time occurred when the dot appeared in the RVF than LVF. The response time to a blank field (no dot) averaged only slightly longer than the reaction time to LVF dot presentations. This appears to demonstrate that the more direct the neural connections within the brain, the faster is the reaction time. However, when they repeated the study using a manual right hand response, they failed to find any laterality differences. A probable explanation for this failure was the confounding of the right-left nature of the stimulus with the required right or left displacement of the response switch. The response was to indicate whether or not a dot had appeared, not whether the dot was in the RVF or LVF. The 40 msec. advantage for a RVF stimulus and a vocal left hemisphere response compares rather well with the results of electrophysiological studies which indicate that it requires approximately 10 msec. (primary positive wave) to 35 msec. (secondary negative wave) for excitation to cross the corpus callosum and its related synapses to the opposite hemisphere (Bremer, 1958; Grafstein, 1959; Teitelbaum, Sharpless & Byck, 1968).

The technique seems to have potential usefulness in laterality studies if one could find the appropriate correspondence between the VF of the stimulus and the laterality of the required response. The reaction time paradigm would allow for more precise quantification of hemispheric differences than do the "recognition" studies. In a preliminary study Simpson (1969) modified Filby & Gazzaniga's technique and extended their findings. The major changes were (1) placing the dot $4^{o}$ from fixation instead of $1^{o}$, (2) using a vertical switch displacement in place of the confounding lateral movement, and (3) testing both right and left hand responses. No change was made in the 100 msec. stimulus exposure time. When a right hand response was required, a RVF stimulus resulted in a 30 msec. faster reaction time than a LVF stimulus. With a left hand response the reverse was found, the LVF yielding a 19 msec. faster reaction time than the RVF. A median of 60 msec. additional time was required for a response to a blank field, a value consistent with the idea that information must cross the corpus callosum twice when the hemispheres "compare notes" to decide that nothing appeared in either visual field.

A follow-up study using randomly occurring single letters or nonsense symbols instead of the dot showed no consistent differences between hand of response, VF, or stimulus form. Blank field responses were only about 20 msec. slower than those to letters or symbols. Experimentally naive, unpracticed college sophomores were used as subjects and it is probable that the initial variability inherent in reaction time tasks had not been overcome. On preliminary trials sophisticated subjects (psychology graduate students and medical students), even though relatively unpracticed, had shown a general tendency to respond quicker to letters when they appeared in the RVF and to respond faster to symbols when they appeared in the LVF.

Gibson, Filby & Gazzaniga (1970) replicated the basic findings of the original study and tested an extension of the underlying theory in which they predicted opposite effects on a task requiring RVF information to be transferred to the right hemisphere and then back again to the left hemisphere for the required verbal response. Their 12 subjects were given a task requiring mental rotation and matching of two figures (e.g.,  = "yes",  = "no"). Nine of the subjects had faster reaction times to stimuli appearing in the LVF and the average for all subjects was 14 msec. faster for LVF stimuli (compared to a 17 msec. advantage for the RVF when they had only to verbally report the presence or absence of a stimulus).

In an effort to combine the methods of Posner with those of Filby and Gazzaniga, Simpson (1970) conducted a preliminary study in which letter pairs were presented tachistoscopically (100 msec.) in either the LVF or RVF and a manual response was made to indicate whether the members of a given pair were "same" or "different." Posner's physical identity level was the basis for decision in one instructional set, while name identity served as the other. The letter pairs subtended a visual angle of $1^{\circ}$ and were located $4^{\circ}$ left or right of the fixation point. Viewing was binocular. With a RVF stimulus (projecting to the left hemisphere) and a right hand response name identity was found to be 35 msec. faster than physical identity. With a left hand response name identity was 15 msec. faster than physical identity. In the LVF the results were mixed. Using a right hand response physical identity was 11 msec. faster than name identity, but--in the left hand response condition name identity was 44 msec. faster than physical identity. In the RVF-right hand condition the same hemisphere mediates both the sensory information processing (name identity) and response initiation, while with the left hand response, time is lost in transfering the response initiation signal to the right hemisphere. The LVF-right hand condition is of approximately the same magnitude as the RVF-left hand condition but shows the expected response of physical identity being faster than name identity.

A manual response reaction time paradigm was used by Geffen, Bradshaw and Wallace (1971) to investigate interhemispheric differences to verbal and non-verbal stimuli. In their first experiment they tachistoscopically presented a 160 msec. stimulus consisting of a line drawing of a human face. The subject's task was to decide if the stimulus face was the same as a previously presented "memory" face. Equal trials were given using the right and left hands, balanced for hand order. "Same" vs. "different" responses were mediated by the second and third fingers of the same hand. They found that LVF stimuli were responded to 25 msec. faster ($p < .01$) than RVF stimuli regardless of hand used for response. Stimuli classified as "different" yielded response times 50 msec. faster ($p < .01$) than "same" responses, suggesting a process of self-terminating serial search in this type of decision making (see Sternberg, 1969). The other experiments reported in this study can be summarized as follows: voice reaction time to faces show no VF differences; voice reaction time to digits--RVF is 10 msec. faster than LVF ($p < .05$); using a manual response to digits, the RVF is 13 msec. faster than the LVF ($p < .05$). No differential sensitivity of the nasal vs. temporal retina was found. In general, non-verbal stimuli were processed faster when presented in the LVF and "stimuli which were verbally encoded and required an identificatory response were processed more quickly when presented in the right visual field." (p. 415)

## Auditory Studies

Kimura (1961a) used the dichotic auditory stimulation technique to demonstrate that if pairs of contrasting digits were presented simultaneously to the right and left ears, those presented to the right ear were reported more accurately. She attributed the effect to the "functional prepotency" of the contralateral pathway connecting the right ear to the language-dominant left hemisphere (Kimura, 1961b). Some electrophysiological studies have provided evidence for stronger contralateral than ipsilateral auditory pathways in the dog (Tunturi, 1946) and cat (Rosensweig, 1951; Hall and Goldstein, 1968). The work of Kimura (1967), and Bocca, Calearo, Cassinari and Migliavacca (1955) on patients with temporal-lobe lesions strongly suggest that this also holds true for man.

The dichotic listening technique has revealed a consistent right ear advantage for verbal material such as digits, words, and consonants (Kimura, 1967; Shankweiler and Studdert-Kennedy, 1967; Darwin, 1971), and for recognition of the speaker's voice (Doehring and Bartholomeus, 1971). However, a left ear advantage is seen in the recognition of non-verbal environmental sounds (Curry, 1967; Knox and Kimura, 1970), melodies (Kimura, 1964, 1967), two-click thresholds (Murphy and Venables, 1970) and simple pitch patterns (Darwin, 1971), although this advantage is less consistent than that found for the right ear. Darwin (1971) has also shown that recall of simple pitch sweeps is also better for the left ear than for the right regardless of whether the sweeps are carried on a word or on a synthetic vowel sound. These studies which demonstrate the left ear superiority for the recognition of non-verbal sound patterns are consistent with the clinical findings of impairment in the discrimination of tonal patterns and timbre following right temporal lobectomy but not after left (Shankweiler, 1966; Milner 1967). The greater effectiveness of the crossed auditory pathway is further confirmed by the work of Milner, Taylor and Sperry (1968) who tested commissurotomized patients on dichotic verbal stimuli. The patients failed to report stimuli to the left ear in the presence of competing stimuli to the right ear. Sparks and Geschwind (1968) have also reported this inhibition of the ipsilateral signal in split-brain patients.

In summary, Kimura's contention that ear advantages in dichotic listening reflect dual cerebral asymmetries of function in perception of verbal and non-verbal stimuli is now supported by much evidence from a variety of sources.

## Neuropsychological Viewpoints

Semmes (1968) has stressed the idea that cerebral dominance or hemispheric specialization of function must have a strong developmental component, brought about by some change in the internal organization within and between the hemispheres. While research over the past decade has more or less concentrated on the verbal-non-verbal aspects of hemisphere function, Semmes suggests that "the hemispheres differ not only in mechanisms of complex behavior but also in processes dealing with input and output. . .the differences at these simpler levels are indicative of a contrast in neural organization which favors hemispheric specialization." (p. 12). Her proposal is that the left hemisphere is focally organized, allowing for fine sensorimotor control, while the right hemisphere has a diffuse organization of elementary functions allowing for integration of dissimilar units, and is specialized for behaviors requiring multimodal coordination, such as spatial organization.

Semmes proposal of a differential functional organization of the hemispheres for both input and output implies that the two hemispheres may also use different mechanisms or systems for the processing of sensory information. This possibility appears worthy of investigation in light of the preliminary findings centered around the work of Filby and Gazzaniga (1969).

In his "Appositional Mind" paper Bogen (1969) claims that the right hemisphere's function is as important as the left hemisphere's, but that this role or function has not yet been established due to the lack of appropriate methods of study. He suggests that this unverified function is that of a comparator of perceptions, schemas and engrams.

If this is the case, it leads to the prediction that stimuli, especially non-verbal stimuli, should be discriminated, compared, or classified more rapidly when they appear in the LVF than when they appear in the RVF. Perceptual recognition of stimuli presented at threshold levels should also be more accurate when presented in the LVF. Bogen does not say that this comparator function extends to verbal stimuli, but recent research reveals a LVF superiority for physical identity matching of letters (Cohen, 1972) and 3 or 4 letter nouns (Gibson, Diamond and Gazzaniga, 1972).

Geschwind (1965), on the other hand, claims that the left hemisphere is dominant over the right for all functions! The exceptions, where the right hemisphere appears to be more efficient on certain restricted types of tasks, he dismisses with the claim that slightly better efficiency on an isolated task does not represent dominance for that task, at least not in the sense that the left hemisphere is dominant for language functions. Lesion studies which suggest that the right parietal lobe exerts primary control of spatial orientation or visuospatial organization are explained by the "fact" of their disconnection from the left hemisphere which exerts the highest level of control. In Geschwind's conception the right hemisphere, with the exception of the primary projection areas, seems to serve only as an input-output accessory for the left hemisphere. Visuospatial organization is thus seen as a function of the left hemisphere, although he does not attempt to assign it to a particular anatomical area (such as the left parietal-temporal association area).

If Geschwind is correct, then one would expect that speed and accuracy of perception and response will be greatest for all classes of stimuli presented in the RVF and the right ear as opposed to LVF and left ear presentations. At least, there should be no category of stimuli which are perceived better by the left ear or in the LVF. The general results of the visual perceptual recognition studies, with their left-hemisphere mediated vocal response, appeared to confirm Geschwind's position. However, many of the more recent studies not only fail to support Geschwind, but offer direct opposition to his stand--especially the reaction time studies in the visual modality and the dichotic auditory stimulation studies.

## Alcohol and Hemispheric Asymmetry

Still another method of investigating brain function is to study it in a chemically altered state, such as while the subject is under the influence of a mildly intoxicating dose of ethyl alcohol. Studies of chronic alcoholism relative to the identification, psychopathology, personality, treatment, and general behavioral aspects of the syndrome can be found throughout the literature. However, there are relatively few studies which have dealt with the neuropsychological deficits associated with alcoholism or acute ingestion of alcohol; studies which could possibly lead us to a more basic understanding of the effects of alcohol on the central nervous system and behavior.

## Studies of Chronic Alcoholics

A brief look at some of the neuropsychological findings reported on chronic alcoholics yields a consistent theme--impairment of visuospatial task performance. Chronic alcoholics have been found to be more field-dependent on the rod and frame test (Karp, Witkin, and Goodenough, 1965), to have very low scores on the Object Assembly and Digit Symbol subtests of the WAIS (Wechsler, 1958) and to do poorly on the Halstead Category Test, which requires visuospatial abstracting ability (Fitzhugh, Fitzhugh, and Reitan, 1960, 1965; Jones and Parsons, 1971). Jones and Parsons (1972) made a detailed analysis of Category Test performance by self-admitted chronic alcoholics on a Veterans Administration hospital alcohol treatment ward. Their findings indicate that chronic alcoholics perform more like brain-damaged patients than control patients. Subtest Four of the test seems to be particularly sensitive to brain pathology and alcoholics are significantly lower on this subtest than control patients, as are all brain-damaged groups. They also report that alcoholics are impaired on the Ravens Progressive Matrices Test, a non-verbal visuospatial test.

The consistent finding of visuospatial impairment in alcoholics suggests that the long-term heavy consumption of alcohol may lead to what appears to be selective lateralized impairment of the right cerebral hemisphere, since such visuospatial impairments are most frequently found in neurological patients with right parietal lobe damage. Since alcohol is diffused throughout the body, including the brain, such seemingly "lateralized" findings appear difficult to interpret. However, an unpublished study by Edelberg (1970) again yields results indicative of differential impairments of the cerebral hemispheres. Using a dichotic listening task, he simultaneously presented conflicting sets of tones, similar to Morse Code, in the left and right ears of "dried-out" chronic alcoholics and age-matched controls. The subjects were instructed to pay attention to only one ear at a time and to report how many short tones occurred in each series, while disregarding the conflicting tones in the other ear. The alcoholics made significantly more left than right ear errors; whereas the controls showed no left-right ear differences. In another dichotic task, where numbers instead of tones were presented simultaneously, the controls showed no significant left-right ear differences (although the right ear was superior), while the alcoholics made significantly more ($t = 4.04$, $p < .001$) left than right ear errors. Edelberg suggested that the alcoholic may have a diminished inhibitory capacity in the right hemisphere as compared to the left. If this is the case, it may be, as Parsons (1969) has suggested, that right hemisphere functions are more easily disrupted than the supposedly more codified, resilient functions of the left hemisphere. A diminished inhibitory capacity in the alcoholic can also be inferred from the work of Coopersmith (1964), and Coopersmith and Woodrow (1967), who report greater verbal and autonomic responsivity in alcoholics as compared to non-alcoholics. In addition, both Edelberg (1970) and Parsons, Tarter and Edelberg (1972) have demonstrated that chronic alcoholics present a "well established deficit" in tasks requiring inhibitory motor control. On such tasks as "draw a three-inch line as slowly as possible without stopping the pencil," or "turn this knob 180$^{\circ}$ as slowly as possible without stopping," the alcoholic fails to perform as slowly as do control subjects. Their findings, that the alcoholic's left hand performance was poorer than his right, and that their left hand performance was significantly poorer than control subjects on both line drawing and knob turning, are suggestive of greater impairment of the right hemisphere than left in alcoholics.

## Studies of Acute Alcohol Doses

Although numerous studies have shown that alcohol, especially in somewhat high doses (blood alcohol concentration (BAC) > 120 mg.%), is detrimental to many types of sensory, cognitive and motor behavior (see reviews by Mardones, 1963; and Kalant, 1970), the results of many studies using low (BAC < 60 mg.%) to moderate (60 mg.% < BAC < 100 mg.%) doses were equivocal. The reviews of Jellinek and MacFarland (1940) and Carpenter (1962) suggest that these contradictory or equivocal results are, in large part, due to general inattention to the basics of good research methodology and analysis on the part of many investigators working in this area. Carpenter (1962) states that the basic focus which psychological research on alcohol should take is to concern itself primarily with the degree and direction of change in function which may occur at these low and moderate BACs.

Somewhat typical of the acute dose studies is the work of Idestrom and Cadenius (1968) who examined the effects of small and moderate doses of alcohol on performance of a number of psychomotor and perceptual tasks. Their low and moderate doses were 0.4 and 0.8 grams alcohol per kilogram (Kg.) of body weight. The "cold strongly flavoured drink containing grape juice and peppermint oil was administered together with two cheese sandwiches." (p. 190). Volume of the drink was based on 500 milliliters (ml.) per 70 Kg. of body weight, and 10 minutes was allowed for consuming the drink. Their results indicate that motor coordination (2 hand speed and accuracy) was impaired at both dose levels, the higher dose showing significant impairment for as long as 90 minutes. No low dose impairment was found on a simple psychomotor function (tapping speed). Choice reaction time was impaired by about 20 msec. at the low dose and 78 msec. at the high dose, the high dose showing impairment for as long as three hours. Critical flicker fusion thresholds were impaired for approximately one hour at the high dose, but the low dose effect did not quite achieve significance. The strongest effects on all tasks were generally found to occur 30-60 minutes after drinking.

Moskowitz and DePry (1968) had subjects perform an auditory divided attention task, similar to that used by Broadbent and Gregory (1963), at a BAC of approximately 80 mg.%. This moderate dose produced no deficit when the subject was instructed to attend to one ear only, even though simultaneous dissimilar stimuli were being presented to each ear. However, a significant deficit was present when instructed to attend to and report information from both ears. This is congruent with the findings of Forney, _et al_. (1961, 1964) and Hughes and Forney (1963) that information processing declines in situations requiring or eliciting divided attention, and that the decline is greater when the subject is under the influence of alcohol than under placebo conditions.

Lewis, Dustman, and Beck (1969) have shown that moderate doses of alcohol (90 mg.% BAC) reduce the amplitude of somato-sensory evoked potentials recorded from the left and right central scalp. However, the visual evoked potential showed a nonsignificant reduction in amplitude on the left; whereas the right central evoked potential was significantly reduced in amplitude ($p < .001$).

The effects of acute doses of alcohol on a complex tracking and signal detection task were investigated by Hamilton and Copeman (1970) in a study designed to give particular attention to changes in selective attention. They instructed their subjects to give the tracking task priority over the signal detection task. Mean BACs of 17 mg.% and 55 mg.% were achieved in two groups of subjects. Alcohol significantly reduced the number of light detections in the periphery of vision and also reduced the efficiency of tracking responses. They concluded that the effect of alcohol was two-fold:

> . . .first an increase in attentional bias toward the high priority regions of the visual field, and the second a decrease in the information transmission rate. Since from the point of view of the tracking task these factors are mutually antagonistic, there may be an offsetting of the loss in transmission rate by more optimal dispositions of attention. (p. 149)

This is similar to the suggestion by Person (1971) that "The net result of low dose phase action may be a narrowing of the perceptual field with a possible enhancement of stimuli at the center of attention. . ." (p. 141).

In the past 15 years research on low and moderate alcohol dose effects has reported such findings as: higher optokinetic fusion thresholds (Blomberg and Wassen, 1962), reduced ability to process two dissimilar channels of auditory information simultaneously (Moskowitz and DePry, 1968), impaired motor coordination on two-hand speed and accuracy tests (Idestrom & Cadenius, 1968), impairment of simple and/or choice reaction times (Idestrom & Cadenius, 1968; Goldberg, 1966; Young, 1970; Tarter, Jones, Simpson and Vega, 1971), impaired spatial task performance (Frankenhaeuser, Myrsten and Jarpe, 1962; Goldberg, 1966), little or no impairment on verbal or inductive reasoning ability (Carpenter, et al., 1961; Frankenhaeuser, Myrsten and Jarpe, 1962), impaired running speed and posture control (Hebbelinck, 1963), prolonged latency in response initiation (Goldberg, 1966), disruption of the correlation between objective and subjective evaluation of performance (Goldberg, 1966), lowered arithmetic performance (Frankenhaeuser, Myrsten and Jarpe, 1962; Ekman, et al., 1964; Goldberg, 1966; Sidel and Pless, 1971), impaired eye-hand coordination in a tracking task (Forney, Hughes and Greatbach, 1964; Hamilton and Copeman, 1970; Sidell and Pless, 1971), neuromuscular incoordination resulting in increased body sway (Romberg Test) or decreased steadiness of the extremities (Goldberg, 1966; Hurst and Bagley, 1972).

## Statement of the Problem

### Hemispheric Differences

The research on the behavioral effects of acute doses of alcohol has neglected what is now a central issue in human neuropsychology--the differential functions of the cerebral hemispheres.

Studies of chronic alcoholism indicate that the prolonged ingestion of alcohol by humans leads to behavioral deficits highly similar to those exhibited by brain-damaged patients (Fitzhugh, Fitzhugh and Reitan, 1960, 1965; Parsons, 1970; Jones and Parsons, 1971, 1972). Some of the studies reviewed above are suggestive of greater right than left hemisphere dysfunction in alcoholics (Edelberg, 1970; Parsons, Tarter and Edelberg, 1972). Such findings raise the question of what happens subsequent to acute doses of alcohol? Do such doses produce similar differential (lateralized?) effects, but on a transient short time base? The literature of the acute studies reveals some interesting findings in this regard. Several studies indicate that low to moderate doses of alcohol produce: an impairment of spatial task performance (Frankenhaeuser, Myrsten and Jarpe, 1962; Goldberg, 1966), impaired block design performance (Pihkanen, 1957), deficit in recognition of figures outlined by dots (Schweitzer, 1955), and Takala, et al. (1958) reported that of several different types of tasks, impairment was most readily seen in those involving spatial factors. (Spatial task performance is generally considered to be a right hemisphere function (Milner, 1971).) Another relevant finding is that of Lewis, Dustman and Beck (1969) who reported a significant amplitude reduction of the visual evoked potential occurring in the right hemisphere but not in the left hemisphere. Such findings seem to merit a deliberate study of possible laterality effects which may result from the ingestion of low to moderate doses of alcohol.

## Task Modality

The rationale for studying the effects of alcohol on motor, sensory and cognitive tasks is based in part on the controversy generated by Jellinek and MacFarland's (1940, p. 363) statement that ". . .psychologists hold that the simple psychological functions are less affected by alcohol than the complex ones, and the experimental evidence certainly tends to bear this out." However, Goldberg (1943) found just the opposite, reporting that intellectual functions, while showing impairment at about the same BAC, were the first to return to baseline performance, and at higher BACs, than the comparatively "simple" sensory and motor tasks.

This finding suggests that intellectual functions are more resistant to alcohol than sensory or motor functions. The ensuing years have produced no clearcut resolution to the problem, but the trend seems to favor Goldberg's findings. It is well to keep in mind Carpenter's (1962) suggestion that the "complex" tasks may be simpler and the "simple" tasks more complex than we usually give them credit for being.

How can the apparently contradictory findings be explained? In many studies the tests were of short duration and well-practiced, giving the subjects an opportunity to "pull themselves together" and "try harder" in an attempt to maintain their self-image of being able to "handle" alcohol without negative effects (Lewis, Dustman and Beck, 1969).

One means of overcoming this "try harder" compensatory behavior is to add a second task which must be performed simultaneously with the primary task. Situations which demand such selective attention have been shown to be sensitive to the effects of alcohol, in many cases leading to a trade-off in which performance on one task is sacrificed in order to maintain performance on the other (Forney, et al., 1961, 1964; Hughes and Forney, 1963; Moskowitz and DePry, 1968; Hamilton and Copeman, 1970).

## Inhibitory Control

The deficits in inhibitory control in alcoholics described by Edelberg (1970) and Parsons, Tarter and Edelberg (1972), together with those which can be inferred from the work of Coopersmith (1964) and Coopersmith and Woodrow (1967) seem to merit further study through the use of acute doses. It is generally recognized that tests of gross muscular coordination (e.g., the Romberg Test) typically yield impaired performance at low and moderate BACs (Pihkanen, 1957; Goldberg, 1943, 1966; Hurst and Bagley, 1972). The exact mechanism of such impaired functioning is not presently known, but it now seems plausible that lessened inhibitory capacity may be involved. In a recent electrophysiological study on cats, Person (1971, p. 140) has suggested that the main effects of a small alcohol dose ". . .appear to be a decrease in the efficiency of inhibitory control over the cerebral cortex." Likewise, one does not have to be a professional researcher to note that persons who "get high" at the cocktail party often lose their social inhibitions. Do such persons also exhibit lack of inhibitory control at other than the social level? The present study attempts to assess the effect of acute alcohol intake upon capacity for inhibitory control.

In summary, this dissertation attempts, through the use of selective attention type tasks, to investigate three general experimental questions relative to the effects of low and moderate acute doses of alcohol:

1. Does acute alcohol intake affect the functions mediated by the right cerebral hemisphere more than those mediated by the left?
2. Is there a differential alcohol effect as a function of task modality, i.e., motor, sensory and cognitive tasks?
3. Does alcohol produce a lowered capacity for inhibitory control?

Questions 1 and 2 are examined in three different tasks; Question 3 is investigated in one task of a motor nature.

The organization of the remainder of the dissertation is as follows: Chapter II contains a complete description of the methodology;

Chapters III through V report three different aspects of the dissertation (At the risk of being somewhat repetitious, this arrangement facilitates consideration of the results from the three different tasks and preparation for publication.); Chapter VI provides a general discussion and summary of the results. In Chapters III through V specific hypotheses are offered. Where relevant, reference is made to the specific experimental questions listed above.

# CHAPTER II

# GENERAL METHODOLOGY

## Subjects

The subjects were 40 right-handed males, 21 to 26 years of age, who characterized themselves as moderate social drinkers. All were college educated, with the majority being either medical or graduate students at the University of Oklahoma Health Sciences Center in Oklahoma City. Each subject was randomly assigned to one of four experimental groups. All received pay for their participation in the study.

## Design

The experimental design involved the use of four independent groups of 10 subjects each. The design is summarized in Table 1, Group I served as a control for alcohol and practice effects, while Groups II and III permitted within-group comparisons of placebo and alcohol doses. Group IV served as a test of moderate dose alcohol effects without benefit of prior practice. Each subject in Groups I, II, and III was tested the second day, exactly 24 hours after their first session.

## Procedure

All subjects were instructed to refrain from eating for a minimum of four hours, and from alcohol for 24 hours, prior to the experimental sessions. Individuals who reported that they were on medication or drugs

TABLE 1

PLACEBO AND ALCOHOL TREATMENTS

| Group | Day 1 | Day 2 |
|---|---|---|
| I | Placebo | Placebo |
| II | Placebo | .88 ml.* |
| III | Placebo | 1.32 ml.* |
| IV | 1.32 ml.* | -- |

*ml. of 95% USP ethanol per kg. of body weight.

were not accepted as subjects. All subjects were told that they could expect to receive varying amounts of alcohol on the two days.

After signing a consent form and being weighed, each subject was given a Breathalyzer test (Stephenson, Model 900) to assure sobriety at the beginning of each test session. On the alcohol dose days, Group II received 0.88 ml. of 95% USP ethanol per Kg. of body weight. Groups III and IV received 1.32 ml. per Kg. Pilot studies in our laboratory showed these doses to produce peak BACs of about 50 mg.% and 100 mg.% respectively. The alcohol was equally distributed across three iced drinks having Wagner Breakfast Orange Drink as a base. The first drink was mixed to a total volume of 230 ml., the other two drinks were mixed to a total volume of 185 ml. The first drink was made "weaker" to allow the subject to become accustomed to the taste of the alcohol. The placebo dose consisted of the same total volumes with three ml. of ethanol distributed around the rim of the glass and floated on top of the drink. While this minute amount of alcohol was sufficient to convince the subject that he had indeed received an alcohol dose, it was insufficient to generate a reading on the Breathalyzer. If the subject thought the placebo dose was "too strong" he was allowed to stir it with the spoon provided with each drink. All subjects were instructed to take about 12 minutes per glass to consume the drinks if they could comfortably do so. Some took longer to complete the three drinks as they were afraid of becoming ill if they drank faster. Ten minutes after cessation of drinking the subject was asked to rinse his mouth thoroughly with water to rid it of residual alcohol. Five minutes later another Breathalyzer sample was taken.

Each subject then performed the four experimental tasks in a fixed order: Cognitive, Motor and Sensory (Auditory and Visual). A breathalyzer sample was taken after each task, as well as midway through the cognitive task, for a total of seven blood alcohol measures. The BAC curves are shown in Figure 1. Approximately 60 minutes elapsed from start of drinking to the beginning of the experimental tasks. These tasks required approximately an additional 90 minutes to complete. If the final BAC was above 50 mg.% the subject was escorted home or released to a friend or relative who agreed to accept responsibility for him. The experimental sessions started as early as 7:30 a.m. and as late as 9:30 p.m., with dose levels being evenly distributed throughout the day. Experimental sessions were conducted for 21 consecutive days.

## Experimental Tasks

A series of four selective attention type tasks was designed to sample the motor, sensory and cognitive functions of the central nervous system.

### Motor Tasks

Knob turning task. The subject was seated in front of a table on which rested an aluminum chassis 10x12x3 inches in size, the large face of which was in the vertical position facing the subject. The knob was 2.38 inches in diameter and centered on the horizontal plane 3.12 inches above the base. The knob, which had a 4 inch black pointer on it, could be rotated freely. Two marks on either side of the face, on the same plane as the center of the knob, indicated the $0^{o}$ to $180^{o}$, otherwise there were no distinguishing marks on the face. The knob was attached

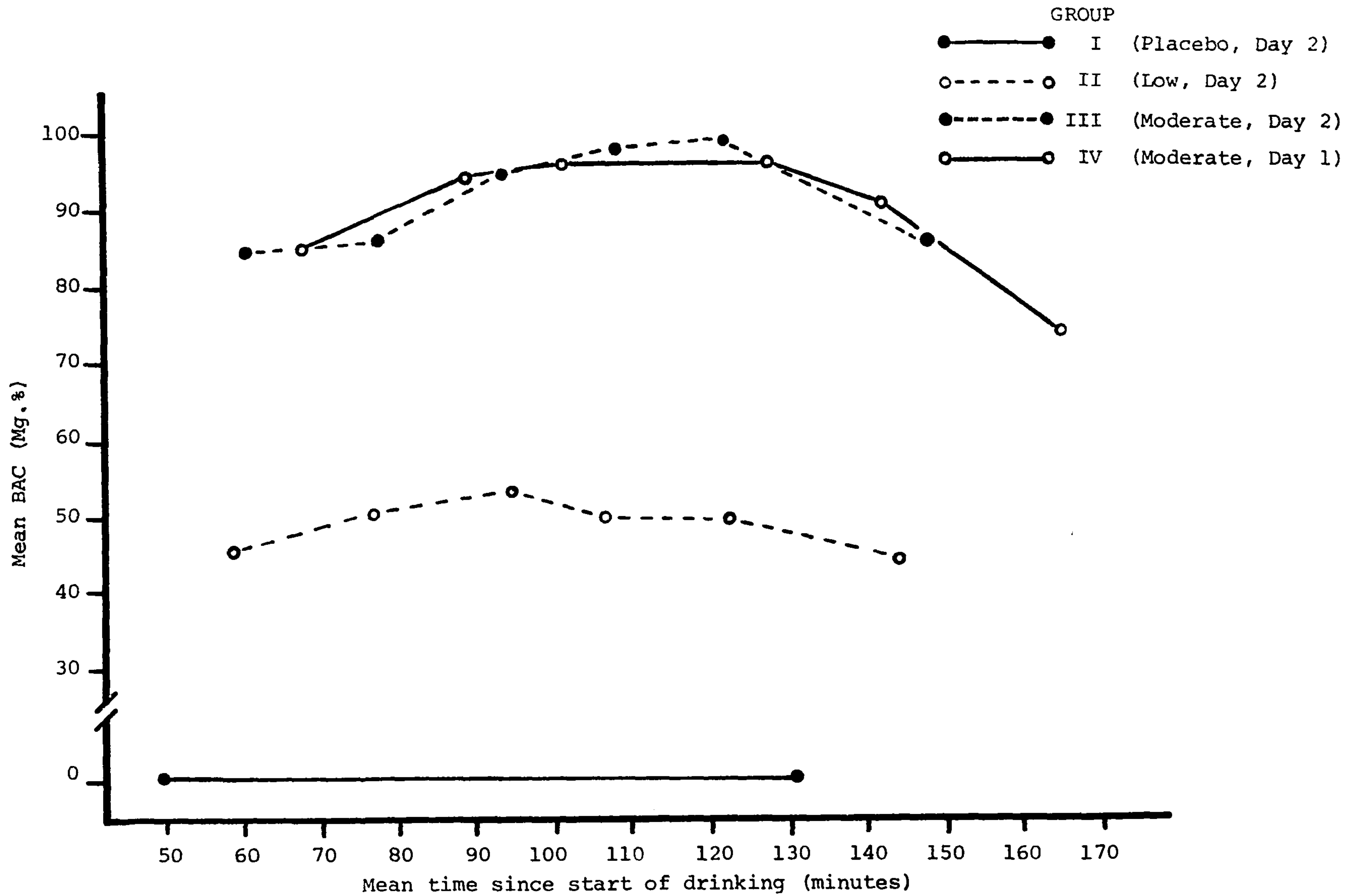


Figure 1. Blood alcohol concentration (BAC) curves.

to the shaft of a linear potentiometer which was part of a simple voltage divider circuit such that the position of the knob was continuously displayed on a polygraph recording, the slope of the line changing with the speed of rotation. The subject was instructed to turn the knob as slowly as possible from one mark ($0^{\circ}$ - $180^{\circ}$) to the other. It was emphasized that the knob should be continuously moving in one direction only. The polygraph recording allowed the monitoring of the subject's performance; i.e., if he stopped turning or reversed direction it would be immediately apparent. Also, the position of the pointer in the $180^{\circ}$ arc could be calculated directly from the polygraph record, as well as the total time elapsed. Hand grasp position on the knob was constant for all subjects. Direction of rotation was clockwise for the right hand, and counter-clockwise for the left hand. Knob turning was scored in terms of total time (seconds) to complete the $180^{\circ}$ sweep, and errors (number of reversals and abrupt pen deflections equal to or greater than 1 millimeter on the polygraph record).

Key pressing task. Simultaneous with the knob turning task, the subject was required to perform a key pressing task with the opposite hand. Key pressing was selected because it involves completely different motor movements and different psychological processes than the knob turning task. The apparatus for the key press task consisted of a small gray metal box from which protruded 5 numbered keyes, each .38 inches wide with approximately .5 inches between keys. The subject was instructed to place the four fingers of one hand on keys 1 through 4 and to press them in a sequentially reversing order, i.e., 1-2-3-4-4-3-2-1-1-2-3-4 etc., at the rate of one press per second. The keys were connected to a voltage divider circuit forming the input to one channel of the polygraph. Each key generated a different line length (height) on the recording, enabling the continuous monitoring of the subject's performance, as well as providing a visual record of response rate, pattern, and errors. The subject was instructed to maintain the prescribed pattern and rate of key pressing for the total duration of the knob turning task, but to concentrate his attention on the knob and sacrifice performance on the key pressing task if he could not maintain consistent performance on both tasks simultaneously. Key pressing was scored in terms of total number of key presses, presses per second, and errors (out of sequence responses, and breaks in the rhythm of the pattern). Each hand performed each task, hand order being alternated across subjects. Each day each subject was allowed to practice performing both tasks together until he attained a criterion of 12 seconds correct rate of key pressing while receiving feedback on his performance.

## Sensory Tasks

There were two sensory tasks, one auditory and one visual, which were cognates of one another. The auditory task was developed by Edelberg (1970), and involved the simultaneous presentation of different sequences of short and long tones (530 Hz, 80 dB) to each ear by means of a stereo tape recorder and stereo earphones. The subject's task was to report the number of short tones heard in one ear while paying no attention to the conflicting set of tones arriving at the other ear. Each sequence lasted four to six seconds and contained five or six tones, one to five of which were short tones. The duration of the short tones was 200 to 250 msec., and that of the long tones was 750 to 1000 msec. The stimulus tape contained 40 sets of tones, the subject reporting 20 from the right ear and 20 from the left ear, in alternating order. The interstimulus interval was 15 seconds. A right-left instruction was given just prior to each sequence. The subject responded by pressing the appropriately numbered key for the number of short tones on a small metal box placed on the table in front of his right hand. The keys were part of a voltage divider circuit connected to one channel of a polygraph, and produced vertical lines of 5 different lengths.

The visual task required the subject to orally report the number of short flashes of light appearing in either the left or right visual field, while maintaining a central binocular fixation and disregarding the conflicting visual signals appearing simultaneously in the opposite visual field. The flashing lights were viewed from a distance of 35.5 cm., $30^{\circ}$ left and right of fixation on the horizontal axis in an enclosure having a flat black interior. A small, dim, "grain of wheat" lamp provided the fixation point. The pattern and timing of the light flashes was identical to that of the tones in the auditory task, the same tape-recorded signals which produced the tones were now used to drive relays which controlled small indicator lamps. The lamps were mounted behind a small sheet of frosted plexiglas having a six millimeter diameter aperture visible to the subject. Tape-recorded instructions informed the subject which stimulus light to attend to while maintaining central fixation. Eye movements during this task were monitored by electro-oculograms which recorded any lateral shift of the eyes, one electrode being placed on the outer canthus of each eye. Scoring was by error analysis, RVF versus LVF.

## Cognitive Tasks

The cognitive tasks involved the tachistoscopic presentation of linguistic stimuli, consisting of upper and lower case letter pairs, in one VF simultaneous with nonverbal stimulus pairs of large and/or small nonsense symbols in the opposite VF. The stimuli were presented in a Dodge type two-field tachistoscope $4^{\circ}$ left and right of central binocular fixation. Each stimulus pair subtened a visual angle of approximately $1^{\circ}$. The subject was instructed to fixate a small red plus sign (+) prior to the presentation of each stimulus card. One-half to two seconds elapsed between the verbal "ready" signal and the onset of the stimulus. Each stimulus card was exposed for 100 msec., assuring adequate time for stimulus recognition while precluding scanning movements of the eyes. The interstimulus interval was 6 seconds. Two levels of instruction were used with each subject. Level I instructions (physical shape identity) asked the subject to report whether or not the nonsense symbols were the same symbol, regardless of size. Level II (name identity) required the subject to report if the letters had the same name. The subject indicated his response by the manual vertical displacement of a small lever switch, e.g., up for "same" and down for "different". The direction of response was alternated across subjects. Response latency in msec. was measured by a Hunter KlocKounter. Reaction time and errors were recorded manually. There were 40 cards in the stimulus deck and the deck was presented four times, once with each hand and level of instruction. Hand sequence was alternated across subjects, but all subjects received Level I instructions before Level II. Ten practice trials were given with each change in hand

and level of instruction.

Responses to all tasks, except cognitive, were recorded on a six channel Beckman Dynagraph, Type R, and/or a Concord monaural tape recorder, Model 350.

# CHAPTER III

## MOTOR TASKS

Casual observation indicates that persons who "get high" drinking alcohol often lose their social inhibitions. Do such persons also experience a lowered degree of inhibitory control at the physiological level, i.e. are the basic inhibitory mechanisms being altered by the acute ingestion of alcohol? It is well-known that consumption of increasingly larger amounts of alcohol (BAC > 100 mg.%) produces a staggering gait and increasing motor incapacity until the person becomes stuporous and collapses (Goldberg, 1943; Mardones, 1963; Kalant, 1970). Tests of gross muscular coordination (such as the Romberg Test for body sway) typically indicate impaired performance at low and moderate doses (BAC $\leq$ 100 mg.%) of alcohol (Pihkanen, 1957; Goldberg, 1943, 1966; Hurst and Bagley, 1972). The exact mechanism of such impaired functioning is not presently known, but it now seems plausible that lessened inhibitory capacity may be involved. Person (1971) has suggested that a significant electrophysiological effect of low ethanol doses (in acute surgical preparation cats) is lessened inhibitory control.

The question of lowered inhibitory control can be evaluated at the human level by requiring the subject to perform a simple motor task <u>as slowly as possible</u>. Such a task was used by Edelberg (1970), and Parsons, Tarter and Edelberg (1972) in studies of "dried-out" chronic alcoholics. They instructed their subjects to turn a large knob through an arc of $180^{\circ}$ as slowly as possible without stopping. The alcoholics turned the knob significantly faster than did control subjects, indicating a lessened ability to inhibit their movements. This diminished capacity could not be accounted for in terms of visual-spatial difficulties, muscle strength, hand tremor, or subjective time overestimation.

However, many studies using low and moderate dose levels have reported little or no impairment in psychomotor functions (Carpenter, 1962; Kalant, 1970), with some studies even indicating improved performance (Enzer, Simonson, and Ballard, 1944; Carpenter, 1961).

Attempts to explain such apparently contradictory findings usually suggest that low alcohol doses may have had an excitatory or stimulating effect on certain aspects of synaptic transmission, even though alcohol is generally classified as CNS depressant (Kalant, 1961, 1970; Mardones, 1963). Another explanation is that such tests are typically of short duration and well practiced, giving the subjects an opportunity to "pull themselves together" and "try harder" in an attempt to maintain their self-image of being able to "handle" alcohol without negative effects (Lewis, Dustman, and Beck, 1969).

One means of overcoming this "tries harder" compensation behavior is to add a second task which must be performed simultaneously with the primary task. Situations which demand such selective attention have been shown to be sensitive to the effects of alcohol, in many cases leading to a trade-off in which performance is sacrificed on one task to maintain performance on the other (Forney, et al, 1961, 1964; Hughes and Forney, 1963; Moskowitz and DePry, 1968; Hamilton and Copeman, 1970). In the case of the knob test described earlier, this analysis suggests that subjects should perform the knob test with one hand and another task with the other hand.

Another question arising from recent research is the possibility that alcohol is more disruptive to the functions mediated by the right cerebral hemisphere than those mediated by the left. Lewis, Dustman, and Beck (1969) reported that moderate doses of alcohol (90 mg.% BAC) reduced the amplitude of the somato-sensory evoked potentials recorded from the left and right central scalp. However, the visual evoked potential showed a nonsignificant reduction in amplitude on the left; whereas the right central evoked potential was significantly reduced in amplitude ($p < .001$). Other acute dose studies report performance impairments similar to those exhibited following right hemisphere brain damage, e.g., impairment of spatial task performance (Frankenhaeuser, Myrsten and Jarpe, 1962, Goldberg, 1943, 1966), and little or no impairment on verbal or inductive reasoning ability (Carpenter, et al, 1961; Frankenhaeuser, Myrsten, and Jarpe, 1962). There are also many similarities between the behavioral deficits exhibited by chronic alcoholics and those exhibited by patients with unilateral right hemisphere brain damage (Parsons, 1970; Jones and Parsons, 1971).

This experiment was therefore designed to explore the following questions: a. Does alcohol in low and moderate doses lead to a lessened degree of inhibitory motor control when the subject must perform two different tasks simultaneously? (Questions 2 and 3, Statement of Problem) b. If an alcohol effect is present, does it affect right hemisphere function more than left? (Question 1, Statement of Problem)

## Method

The methodology was completely described in Chapter II (p. 30).

## Results

### Blood Alcohol Concentrations

The means and standard deviations of the BACs for each of the alcohol groups before and after the motor task are shown in Table 2.

It should be noted that subjects who received the smaller dose (Group II) and weaker concentration reached their peak sooner than those subjects receiving the larger dose (Groups III and IV) and therefore were tested further down the descending limb of the BAC curve than were the larger dose subjects who were tested at or near their peak BAC, with many subjects being on the ascending limb of the BAC curve.

### Knob Turning Task

The means and standard deviations for knob turning time are presented in Table 3. Most analyses were based on differences between Day 1 and Day 2 to control for variability in baseline performance levels. While Day 1 mean knob turning times across Groups I, II, and III did not differ significantly ($F < 1$, $df = 2, 27$) for either the left or right hands, they did differ in variance (Left hand, $F_{max} = 26.17$, $df = 9$, $p < .01$; right hand, $F_{max} = 9.12$, $df = 9$, $p < .01$). There was a significant main effect of alcohol for the left hand (Kruskal-Wallis One Way Analysis of Variance by Ranks, $H = 7.605$, $p < .025$), and also for the right hand ($H = 6.511$, $p < .05$)[1]. Group I, the placebo group, turned the knob significantly

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[1]All probability values are two-tailed unless otherwise noted.

TABLE 2

MEANS AND STANDARD DEVIATIONS FOR TIME OF STARTING AND FINISHING MOTOR TASK AND BLOOD ALCOHOL CONCENTRATIONS (BAC)

| Group | | Minutes* | | | BAC (Mg%) | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Before | After |
| I | Mean | 83.5 | 55.7 | 95.3 | -- | -- |
| | S.D. | 13.5 | 12.7 | 13.8 | -- | -- |
| II | Mean | 94.8 | 57.6 | 103.7 | 53 | 50 |
| | S.D. | 10.9 | 8.4 | 10.1 | 9 | 6 |
| III | Mean | 96.0 | 57.7 | 106.1 | 94 | 98 |
| | S.D. | 11.5 | 6.9 | 11.6 | 16 | 13 |
| IV | Mean | 110.3 | 63.7 | 124.9 | 97 | 96 |
| | S.D. | 8.7 | 10.8 | 12.9 | 17 | 15 |

*1. From start of drinking to start of task

2. From end of drinking to start of task

3. From start of drinking to end of task

TABLE 3

MEANS AND STANDARD DEVIATIONS FOR EACH GROUP
FOR KNOB TURNING TIME IN SECONDS

| Group | Left Hand | | | | Right Hand | | | |
|---|---|---|---|---|---|---|---|---|
| | Day 1 | | Day 2 | | Day 1 | | Day 2 | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| I | 194.5 | 102.4 | 230.0 | 109.5 | 257.7 | 139.7 | 288.6 | 145.1 |
| II | 192.9 | 53.7 | 162.3 | 44.1 | 222.5 | 94.5 | 193.4 | 76.9 |
| III | 260.3 | 274.9 | 194.9 | 189.6 | 295.5 | 285.6 | 235.2 | 190.3 |
| IV | 228.9 | 151.0 | -- | -- | 241.2 | 240.8 | -- | -- |

slower (better) than either of Groups II or III on Day 2. Inspection of Table 3 also indicates that knob turning is slower in the right hand than in the left hand. Group IV showed no significant increase in knob turning time with either hand when compared to the other three groups on Day 1.

The Mann-Whitney U-Test was used to make multiple comparisons between Hands and Groups in Groups I through III, as shown in Table 4. The only pairings yielding significant U values were those involving the placebo group. Differences between the low and moderate dose alcohol groups, while in the predicted direction, did not achieve significance. Table 5 indicates the difference and percent change in mean knob turning time from Day 1 to Day 2 by Hand and Group. The placebo group improves with practice on Day 2 while the two alcohol groups show a somewhat linear decrease in knob turning time with increasing alcohol dosage. It is obvious that no differences were found in percent change in the left hand compared to the right hand in either alcohol group.

Errors. Inspection of Table 6 indicates that alcohol reduces the smoothness and accuracy of motor control in a somewhat linear fashion. As BAC increased, knob errors increased (Spearman rank order correlation for left hand: $r_s = .373$, $p < .05$; right hand: $r_s = .503$, $p < .005$).

Essentially zero point bi-serial correlations between knob turning time and high versus low knob errors indicate that knob turning time and knob errors are independent measures of the alcohol effect (left hand: $r. = -.015$; right hand: $r. = -.007$).

The Kruskal-Wallis analysis of difference scores yields significant alcohol effects for knob errors in both left and right hands ($H = 5.089$ and $4.946$ respectively; $p < .05$ one tail).

TABLE 4

MANN-WHITNEY U VALUES OF DIFFERENCE SCORES FOR KNOB TURNING TIME BY HAND AND GROUP

| Groups | Left Hand | | | Right Hand | | |
|---|---|---|---|---|---|---|
| | I | II | III | I | II | III |
| Left | | | | | | |
| I | -- | 17.5** | 19.0** | | | |
| II | | -- | 45.5 | | | |
| III | | | -- | | | |
| Right | | | | | | |
| I | | | | -- | 19.0** | 23.0* |
| II | | | | | -- | 47.0 |
| III | | | | | | -- |

*p < .05

**p < .02

TABLE 5

DIFFERENCE IN SECONDS AND PERCENT CHANGE IN MEAN KNOB TURNING TIME FROM DAY 1 TO DAY 2

| Group | Left Hand | | Right Hand | |
|---|---|---|---|---|
| | Seconds | % | Seconds | % |
| I | +35.5 | +18.2 | +31.1 | +12.1 |
| II | -30.6 | -15.9 | -29.1 | -13.1 |
| III | -54.8 | -21.0 | -60.3 | -20.4 |

TABLE 6

TOTAL KNOB TURNING ERRORS AND DIFFERENCE SCORES
FOR EACH GROUP BY HAND AND DAY

| | Left Hand | | | Right Hand | | |
|---|---|---|---|---|---|---|
| Group | Day 1 | Day 2 | Diff. | Day 1 | Day 2 | Diff. |
| I | 3 | 0 | 3 | 3 | 2 | 1 |
| II | 3 | 9 | -6 | 5 | 8 | -3 |
| III | 2 | 15 | -13 | 2 | 16 | -14 |
| IV | 14 | -- | -- | 25 | -- | -- |

There is a significantly higher proportion of subjects who made errors in the alcohol groups than in the placebo group. An analysis of difference scores (Day 1 minus Day 2 errors) yields a chi square of 6.72, df = 2, $p < .05$.

The effect of alcohol upon knob turning errors is evident when Group IV is compared to the other groups on Day 1 and with the alcohol dose groups on Day 2. The left hand of Group IV subjects had more than four times the errors of the others on Day 1, and about the same errors as the left hand of Group III on Day 2. The right hand errors for Group IV were even greater, 25 as compared to not more than 5 for each of the other groups on Day 1, and 50% greater than the Group III alcohol dose performance. These results indicate that while Group IV does not demonstrate significant impairment in knob turning speed, its error rate is significantly higher, especially in the right hand.

## Key Press Task

Rate. The means and standard deviations for key press rate (presses per second) are presented in Table 7. The Kruskal-Wallis analysis of difference scores (Day 1 minus Day 2) indicates a significant slowing of key press rate due to alcohol ($H = 9.081$, $p < .025$) in the left hand, but not in the right hand ($H = .2073$, p = NS).

A Wilcoxon T test for unpaired replicates was applied to the difference scores for multiple comparisons between Hands and Groups. The computed T values are shown in Table 8. The significant slowing of left hand key press rate is confined to the moderate dose group.

Group IV's key press rate was significantly slower than the other

TABLE 7

MEANS AND STANDARD DEVIATIONS FOR EACH GROUP FOR KEY PRESS RATE (PRESSES PER SECOND)

| Group | Left Hand | | | | Right Hand | | | |
|---|---|---|---|---|---|---|---|---|
| | Day 1 | | Day 2 | | Day 1 | | Day 2 | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| I | 1.14 | .24 | 1.01 | .31 | 1.22 | .39 | 0.97 | .28 |
| II | 1.04 | .47 | 1.10 | .54 | 1.12 | .50 | 1.01 | .53 |
| III | 1.34 | .63 | 1.06 | .51 | 1.20 | .44 | 1.07 | .51 |
| IV | 0.85 | .16 | -- | -- | 0.91 | .14 | -- | -- |

TABLE 8

VALUES OF WILCOXON T FOR UNPAIRED REPLICATES USING KEY PRESS RATE DIFFERENCE SCORES

| Groups | Left Hand | | | Right Hand | | |
|---|---|---|---|---|---|---|
| | I | II | III | I | II | III |
| Left | | | | | | |
| I | -- | 92.0 | 73.0* | | | |
| II | | -- | 70.5* | | | |
| III | | | -- | | | |
| Right | | | | | | |
| I | | | | -- | 85.5 | 92.5 |
| II | | | | | -- | 102.5 |
| III | | | | | | -- |

Critical value of T is $\leq 79$

*$p < .05$

three groups on Day 1 in both the left and right hands (*t* = 3.179 and 2.955 respectively, df = 38, $p < .01$). No differences in key press rate were found in Group IV between left and right hands (*t* < 1, df = 9) or between Group IV and Group III Day 2 (left hand *t* = 1.213, df = 18, p = NS; right hand *t* < 1, df = 18). In terms of the amount of deviation from the instructed rate of one press per second, Group IV differs in that it performed slower, and the other groups pressed faster than instructed. Group IV was much more consistent in its performance than were the other three groups. Left hand key press rate showed a negative, but non-significant correlation with right hand knob turning time (*r* = -.412). No correlation was found for right hand key press rate and left hand knob turning time (r = -.076).

Errors. The means and standard deviations for key press errors are presented in Table 9. Left hand key errors show a significant positive correlation with BAC ($r_s = .341$, $p < .05$). The right hand correlation did not attain significance ($r_s = .148$). Such findings are suggestive of a right hemisphere effect of alcohol.

The Kruskal-Wallis analysis of difference scores for left hand key errors yields an H value of 4.226, p = NS. For the right hand the H is 6.961, $p < .05$. This significant right hand effect is due to the extremely high error rate of Group III on Day 1 which showed a 65% reduction on Day 2. It should be noted that the right hand errors for this group on the alcohol day are still 50% greater than the placebo group on Day 2, and the left hand errors are double that of the placebo group. Group III left hand key errors are about 20% higher than the other two groups on Day 1, and the right hand errors show three times the error

TABLE 9

MEANS AND STANDARD DEVIATIONS FOR KEY PRESS ERRORS BY HAND, GROUP AND DAY

| Group | Left Hand | | | | Right Hand | | | |
|---|---|---|---|---|---|---|---|---|
| | Day 1 | | Day 2 | | Day 1 | | Day 2 | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| I | 10.0 | 11.54 | 5.4 | 5.81 | 5.0 | 5.83 | 4.1 | 4.58 |
| II | 10.6 | 7.83 | 13.2 | 8.68 | 5.7 | 4.36 | 5.8 | 4.85 |
| III | 12.2 | 7.93 | 10.8 | 6.05 | 17.5 | 22.46 | 6.1 | 6.33 |
| IV | 7.5 | 11.84 | -- | -- | 7.5 | 10.23 | -- | -- |

rate of Groups I and II, indicating that random assignment of subjects to conditions did not work with respect to this variable.

Group IV had fewer mean errors on Day 1 than the other three groups, but these differences were not significant for either hand ($t < 1$, df = 38). Likewise, they do not differ from those of Group III, Day 2 ($t < 1$, df = 18).

## Discussion

The major finding of the present study is that alcohol in low and moderate acute doses leads to a lessened degree of inhibitory motor control, and the effect is present in both left and right hand performance. This deficit in inhibitory motor control is much in evidence even at low BACs ($\bar{x}$ = 53 mg.%) and gets progressively worse with increasing amounts of alcohol ($\bar{x}$ = 95 mg.%).

The difference score analyses, wherein each subject serves as his own control, contribute substantially to the validity and significance of the findings, since demonstration of an alcohol effect requires it to override the improvement resulting from practice obtained on the first day. Hence, any significant results based on difference scores are necessarily conservative evaluations.

The detrimental effect of alcohol upon inhibitory motor control is further demonstrated by the significant positive correlation between BAC and the number of knob turning errors. Again, the effect is present in both hands. The alcohol effect is also shown by the increasing proportion of subjects making errors as a function of BAC. Eighty percent of the moderate dose groups, 60% of the low dose group and only 20% of the placebo group made errors in knob turning.

The "trade off" reported by Forney, et al, (1961) and others, in which performance under alcohol is sacrificed on one task to maintain performance on another, does not seem to have occurred in this study. This was the case despite the instructions which emphasized that, if necessary, the subject should sacrifice performance on the key press task to maintain his performance on the knob test. Why this "trade off" did not occur is difficult to assess but may lie in the nature of the key press task which consisted of establishing a constant rhythm and order of response, a relatively easily programmed response. Alcohol may not interfere with this type of performance as compared to the knob turning inhibitory task where constant monitoring is necessary.

The second focus of this study is the question of a greater right hemisphere effect of alcohol. While no major evidence was found for a differential right hemisphere effect, it should be noted that only the left hand key press errors show a significant positive correlation with BAC. It seems that if there is a real, but subtle, differential effect of alcohol upon the right hemisphere, it would be most likely to appear when the left hand was performing the less important secondary task while the right hand was concentrating on the performance of the primary task of knob turning.

The significant Kruskal-Wallis value for left hand key press rate suggests that alcohol produced an impairment on this task. While the decrease in rate on Day 2 might be viewed as a "normalizing" effect, it can be argued that the random assignment of subjects to conditions did not work well with respect to key pressing, therefore, the subjects in

Group III had a different concept of what one key press per second "felt like" and the high rate (34% faster than instructed or practiced) on Day 1 was "normal" for them, and the 21% slowing on Day 2 is a deficit due to alcohol. This latter interpretation is consistent with other results in the study.

A neuropsychological question now arises. What circuits in the brain are being affected by alcohol to produce the observed deficits? Those circuits most likely to be impaired seem to be the frontal-limbic-diencephalic ones which are directly involved in the sub-cortical motivational systems, and which, among other things, exert inhibitory controls upon behavior (Stamm, 1973; Milner, 1970). In this respect, damage to the frontal lobes in man has been shown to produce disturbances in the temporal ordering of events (Milner, 1971; Pribram, 1969; Milner and Teuber, 1968; Pribram and Tubbs, 1967), motor disinhibition, especially when proprioceptively guided (Corkin, 1965), and inability to maintain motor sets (Luria, 1966).

In summary, while most alcohol experiments have concentrated on showing that speed of reaction is slowed, the present experiment has demonstrated that behavior at the other end of the scale is also affected. Alcohol, in contrast to placebo, diminishes the capability of subjects to turn a knob "as slowly as possible". (In interpreting the inhibitory difficulties demonstrated in this study it is well to remember that the subject was required to perform two different tasks simultaneously and no test was made of single task performance.) In many life situations, i.e., driving, industrial shop work, etc., both speed of reaction and slow, controlled motor activity is needed for satisfactory performance.

Alcohol, even in low doses (50 mg.%), is likely to render the drinker more vulnerable to impaired performance on a variety of life tasks. Alcohol was not found to have significant laterality effects in knob turning, however, some suggestion of greater alcohol effect on the left hand key pressing task was noted.

# CHAPTER IV

# SENSORY TASKS

This investigation studies the differences in hemispheric functional asymmetry and the effects of low and moderate doses of alcohol upon two sensory tasks, one auditory and one visual, which are cognates of one another.

## Hemispheric Functional Asymmetry

Dichotic auditory studies have demonstrated a left ear superiority for non-verbal environmental sounds (Curry, 1967; Knox and Kimura, 1970), melodies (Kimura, 1964, 1967) and simple pitch patterns (Darwin, 1971). Since the present study uses non-verbal tonal patterns it is hypothesized that

a. the dichotic auditory task will reveal better left than right ear performance under the placebo dose conditions.

In the visual modality, the work of Kimura (1966) indicates a LVF superiority for enumeration of tachistoscopically presented non-verbal stimuli. A LVF superiority for non-verbal visual designs has also been reported by Schell and Satz (1970). Since the present study requires the subject to count (enumerate) certain aspects of a non-verbal visual display in one visual field while disregarding competing stimuli in the other visual field, it is hypothesized that

b. under placebo dose conditions, LVF stimuli on a visual cognate of the dichotic auditory task will be perceived more accurately than RVF stimuli.

## Alcohol Effects

From the review of the literature, it appears that alcohol impairs dichotic auditory task performance when the subject is required to process two dissimilar channels of information simultaneously but not when he is required to attend to only one channel and disregard the other (Moskowitz and DePry, 1968). The present study uses dichotic type tasks in which both channels have identical but conflicting stimuli being presented simultaneously, and the subject is required to attend to one channel only and disregard the conflicting stimuli in the other channel. In view of this apparent increase in task complexity it is suggested that

c. performance on a dichotic auditory task which uses similar but conflicting non-verbal tonal patterns will be impaired following ingestion of low and moderate doses of alcohol (Question 2, Statement of Problem)

   and

d. these same alcohol doses will result in impaired performance on the visual cognate of the auditory task. (Question 2, Statement of Problem)

Finally, if an alcohol effect is demonstrated on either or both of the sensory tasks

e. alcohol will disrupt right hemisphere functions more than left. (Question 1, Statement of Problem)

## Method

The methodology was completely described in Chapter II (p. 33).

## Results

The means, standard deviations and Day 1 minus Day 2 difference scores for stimuli presented to the left and right ears are shown in Tables 10 and 11 respectively. The same information for left and right visual fields is shown in Table 12.

### Hemispheric Functional Asymmetry

Hemispheric functional asymmetry was assessed by pooling the Day 1 placebo dose scores of Groups I, II and III. Due to the presence of zero error scores for some subjects, and proportional relationships between the means and standard deviations, a log transformation ($\log_{10}(X + 1)$) was applied to each subject's total error score and these values were analyzed by use of the $t$ test. As predicted, for the auditory task right ear errors were greater than left ear errors ($t = 1.574$, df = 28, $.10 > p > .05$, one tailed test) but failed to achieve statistical significance. Hypothesis a therefore received only weak tentative support at best.

In the visual modality, LVF errors were found to be greater than RVF errors ($t = 1.781$, df = 28, $.10 > p > .05$). This is opposite of the prediction made in Hypothesis b.

### Alcohol Effects

Blood alcohol concentration. The means and standard deviations for times from beginning and ending of drinking to the start and finish of the auditory and visual tasks, as well as BACs are presented in Table

TABLE 10

MEANS, STANDARD DEVIATIONS, AND DIFFERENCE
SCORES FOR AUDITORY TASK ERRORS
LEFT EAR

| Group | Day 1 | | Day 2 | | Difference | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| I | 3.20 | 3.36 | 2.20 | 2.39 | 1.00 | 1.83 |
| II | 2.70 | 2.71 | 3.30 | 2.79 | -0.60 | 3.03 |
| III | 2.90 | 3.31 | 2.50 | 2.37 | 0.40 | 2.50 |
| IV | 4.90 | 5.02 | -- | -- | -- | -- |

TABLE 11

MEANS, STANDARD DEVIATIONS, AND DIFFERENCE
SCORES FOR AUDITORY TASK ERRORS
RIGHT EAR

| Group | Day 1 | | Day 2 | | Difference | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| I | 3.50 | 3.10 | 2.60 | 2.67 | 0.90 | 3.14 |
| II | 3.00 | 2.21 | 2.10 | 1.45 | 0.90 | 1.60 |
| III | 3.50 | 3.37 | 1.60 | 1.65 | 1.90 | 2.13 |
| IV | 5.20 | 4.66 | -- | -- | -- | -- |

TABLE 12

MEANS, STANDARD DEVIATIONS, AND DIFFERENCE SCORES FOR VISUAL TASK ERRORS

| Group | Day 1 | | Day 2 | | Difference | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Left Visual Field | | | | | | |
| I | 5.40 | 3.84 | 3.60 | 4.35 | 1.80 | 2.62 |
| II | 4.80 | 4.26 | 4.70 | 4.42 | 0.10 | 5.47 |
| III | 3.80 | 3.49 | 3.40 | 2.80 | 0.40 | 1.71 |
| IV | 4.80 | 3.61 | -- | -- | -- | -- |
| Right Visual Field | | | | | | |
| I | 4.10 | 3.57 | 3.60 | 3.57 | 0.50 | 2.80 |
| II | 3.70 | 3.20 | 4.30 | 3.23 | -0.60 | 3.17 |
| III | 3.00 | 2.98 | 3.50 | 3.21 | -0.50 | 1.35 |
| IV | 5.30 | 5.21 | -- | -- | -- | -- |

13. Groups II and IV were on the descending limb of the blood alcohol curve throughout both tasks, while Group III appears to have reached peak sometime during the auditory task while the visual task was performed on the descending limb. This suggests that auditory task performance in Group III may have been more affected by alcohol than the visual task.

Error analysis. Comparisons between Groups I, II and III were based on difference scores (Day 1 minus Day 2) to control for variability in baseline performance levels. Kruskal-Wallis analyses of these difference scores fail to demonstrate a significant alcohol effect for ear (left ear, $H = 1.89$, $df = 2$, $p = NS$; right ear, $H = 1.20$, $df = 2$, $p = NS$), or visual field (LVF, $H = 1.10$, $df = 2$, $p = NS$; RVF, $H = 1.79$, $df = 2$, $p = NS$). Hypotheses c, d, and e were not supported.

The monitoring of eye movements by electro-oculograms proved to be an effective means of controlling central fixation on the visual task. Only three of the 40 subjects made eye movement errors, and those few errors which did occur did not tend to aid the subject's performance. Therefore, eye movement errors were omitted from the analysis of the visual task performance.

A comparison of the Day 1 placebo dose error scores for Groups I, II and III with the moderate alcohol dose error scores for Group IV also fails to demonstrate an alcohol effect on ear or visual field (left ear, $H = 0.08$, $df = 3$, $p = NS$; right ear, $H = 1.63$, $df = 3$, $p = NS$; LVF, $H = 1.31$, $df = 3$, $p = NS$; RVF, $H = 3.41$, $df = 3$, $p = NS$).

A log transformation was applied to the total error score for each subject for each treatment condition in an attempt to reduce the propor-

TABLE 13

MEANS AND STANDARD DEVIATIONS FOR TIME OF STARTING AND FINISHING THE SENSORY TASKS AND BLOOD ALCOHOL CONCENTRATIONS (BAC)

| Group | | Minutes* | | | | | BAC (Mg. %)** | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | 1 | 2 | 3 |
| I | Mean | 69.7 | 97.5 | 107.6 | 116.4 | 126.5 | -- | -- | -- |
| | S.D. | 12.3 | 13.5 | 12.3 | 14.7 | 14.1 | -- | -- | -- |
| II | Mean | 70.3 | 107.5 | 118.8 | 127.0 | 139.1 | 50 | 50 | 45 |
| | S.D. | 9.6 | 12.0 | 13.4 | 11.4 | 11.7 | 7 | 8 | 7 |
| III | Mean | 72.5 | 110.8 | 120.4 | 130.4 | 145.3 | 98 | 99 | 87 |
| | S.D. | 11.1 | 12.2 | 12.1 | 12.0 | 12.5 | 13 | 14 | 16 |
| IV | Mean | 82.2 | 128.8 | 138.9 | 146.8 | 161.1 | 96 | 91 | 74 |
| | S.D. | 16.3 | 13.1 | 12.9 | 14.9 | 14.4 | 15 | 14 | 12 |

*A. From end of drinking to start of Auditory Task
B. From start of drinking to start of Auditory Task
C. From start of drinking to end of Auditory Task
D. From start of drinking to start of Visual Task
E. From start of drinking to end of Visual Task

**1. Before Auditory Task
2. Between Auditory and Visual Tasks
3. After Visual Task

tional relationship of the means and standard deviations. The appropriate independent or correlated means *t* tests were then run on selected treatment conditions having the largest mean differences, but no significant values were obtained.

In general, the results of the alcohol data analysis lends little or no statistical support for Hypotheses c and d, nor is there statistically significant evidence of a lateralized effect of alcohol (Hypothesis e).

Spearman rank order correlations were computed between auditory errors and visual errors within hemispheres and across days. The obtained values for left hemisphere stimuli (right ear and RVF) are: Day 1, $r_s = .582$; Day 2, $r_s = .646$. The correlations for right hemisphere stimulation (left ear and LVF) are: Day 1, .513; and Day 2, .716. All $r_s$ values are significant beyond the 0.01 level (Groups I, II, III, N = 30). These significant positive correlations suggest that the cognate auditory and visual tasks are mediated in part by central processes in addition to modality specific functions.

With respect to the number of subjects within each group showing improvement (fewer errors) on Day 2, 70% of the placebo subjects improved in the RVF on the visual task while only 25% of the alcohol subjects did so (chi square = 3.906, df = 1, $p < .05$). No appreciable differences were found between placebo and alcohol groups for LVF or left and right ear errors, the largest difference being 15%.

## Discussion

While not achieving significance, the basic differences between the various conditions of the auditory task are in the predicted direction. The results (Group I, II, III) indicate fewer total errors in the left ear on Day 1 (right hemisphere slightly better), and a slight increase in total errors on Day 2 in Groups II and III (possible mild alcohol effect); whereas the right ear errors decrease sharply on Day 2, similar to the significant practice effects present in Group I for each ear. These results are suggestive of a weak lateralized alcohol effect upon the right hemisphere, and are at least congruent with other research reporting better tonal pattern recognition in the left ear (Kimura, 1964, 1967; Darwin, 1971).

Group IV shows little difference between ears, but the high mean error rate and large standard deviations suggest that this group was affected by the alcohol, but in a non-systematic fashion.

Refining the task and/or procedure by increasing task complexity or providing for several practice sessions should reduce the high intra-group subject variability in future studies using similar tasks.

The visual task data reveals a strong practice effect for the LVF in Group I and a mitigation of this effect by alcohol in Groups II and III. The Group I practice effect is less evident in the RVF and Groups II and III show an increase in errors with alcohol. As in the auditory task, the high intra-group subject variability prevents the observed differences from achieving significance.

Two findings are of interest with respect to the issue of hemispheric functional asymmetry and laterality of alcohol effects in the visual task. First, the placebo day finding of RVF errors being less than the LVF errors (opposite of what was predicted), and second, the poorer performance in the RVF for the alcohol groups on the alcohol dose day, again, the opposite of expectancy. These findings suggest that a left hemisphere superiority may exist for this particular visual task and that alcohol somewhat selectively interferes with this functional superiority.

This suggests that in the visual task stimulus quality (the non-verbal character of the light flashes) may not have been the critical variable, but instead, the subvocal counting activity mediated by the verbal-mathematical left hemisphere (see Luria, 1966a, 1966b; Sperry, 1967) may be of primary importance. In support of this idea, it can be argued that the temporal pattern of light flashes does not constitute a significant visuospatial component to require processing by the right hemisphere even though the stimulus itself is non-verbal in character.

Kinsbourne's (1970) attentional hypothesis may also be relevant to the visual task in that the required response was oral, thus producing an attentional bias in favor of the left hemisphere, and thus lower error scores in the RVF.

The temporal pattern requiring a "counting" type of analysis could also be the explanation for the small laterality differences observed in the auditory task, suggesting a sharing of the information processing load by the supposedly tonal pattern superior right hemisphere and the verbal-mathematical superior left hemisphere.

The general absence of a strong alcohol effect cannot be attributed to the idea that the tasks do not reflect operation of central brain processes. The significant positive correlations between performances on the auditory and visual tasks preclude such an explanation. The more likely explanation is based on Jones' (1972) finding that performance is much more disrupted on the ascending limb of the blood alcohol curve than on the descending limb. Since the sensory tasks were performed about two hours after the start of drinking the majority of the subjects were well into the descending limb of the curve.

# CHAPTER V

# COGNITIVE TASK

The cognitive task experiment is an extension and modification of the author's earlier work (Simpson, 1970) and was designed to assess (1) differences in hemispheric functional asymmetry, and (2) the effects of low and moderate doses of alcohol upon the behaviors used to assess such asymmetry.

## Hemispheric Functional Asymmetry

The studies cited in Chapter I which deal with hemispheric functional asymmetry suggest that the hemispheres differ in their efficiency of processing information, and that part of this difference is probably due to the nature of the stimuli being processed. The left hemisphere is generally superior in the processing of verbal stimuli, while several studies suggest that the right hemisphere is better than the left in the processing of non-verbal stimuli. It therefore seems appropriate to hypothesize that due to the familiarity of verbal stimuli

a. reaction time to verbal stimuli will be faster than to novel non-verbal symbols, and

b. errors will be fewer for verbal stimuli than for novel non-verbal symbols;

with respect to hemispheric differences that

c. reaction times to verbal stimuli will be faster when presented in the RVF than in the LVF,

d. reaction times to non-verbal stimuli will be faster when presented in the LVF than in the RVF,

e. errors will be fewer when verbal stimuli are presented in the RVF than in the LVF,

f. errors will be fewer when non-verbal stimuli are presented in the LVF than in the RVF.

## Alcohol

The study of acute dose alcohol effects upon cognitive functioning is intended to assess the following hypotheses.

g. Alcohol in low and moderate acute doses will result in a slowing of reaction time. (Question 2, Statement of Problem)

If a slowing is demonstrated,

h. Alcohol will have a greater effect on reaction times to stimuli appearing in the LVF than to those appearing in the RVF. (Question 1, Statement of Problem)

Since alcohol is known to adversely effect the accuracy of response in many task situations

i. Low and moderate acute doses of alcohol will result in higher error rates. (Question 2, Statement of Problem)

If higher error rates are observed,

j. Errors will be more numerous in the LVF than in the RVF as a function of alcohol. (Question 1, Statement of Problem)

## Method

The methodology was completely described in Chapter II (p. 35).

## Results

The means and standard deviations of median reaction times for each group, under each experimental condition are shown in Table 14. The same information for error scores is presented in Table 15.

### Hemispheric Functional Asymmetry

Reaction time. Tests for hemispheric functional asymmetry were made by pooling the Day 1 placebo dose values for all subjects ($n = 30$) and performing a 2 (visual field) X 2 (letter-symbol) X subjects analysis of variance (Lindquist, 1953). For visual field $F = 3.81$, $df = 1, 29$, $.10 > p > .05$, for letter-symbol $F = 4.13$, $df = 1, 29$, $.10 > p > .05$[2], and the visual field by letter-symbol interaction $F = 5.49$, $df = 1, 29$, $p < .05$ (Figure 2). Reaction time to symbols is 34.4 msec. faster in the LVF than RVF ($t = 3.203$, $df = 28$, $p < .01$). Letters are 5.8 msec. faster in the RVF than LVF, but this small difference fails to be significant ($t < 1$, $df = 28$). These results support hypothesis a, that reaction times to verbal stimuli will be faster than to novel non-verbal symbols, and hypothesis d, that reaction time to non-verbal stimuli will be faster in the LVF than in the RVF. No support is found for hypothesis c, that reaction times to verbal stimuli will be faster when presented in the RVF than in the LVF, even though the means were in the predicted direction.

Errors. The same analysis of variance was performed on the error

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[2]One-tailed t tests for visual field and letter-symbol were significant ($p < .025$ and $< .05$ respectively).

TABLE 14

MEANS AND STANDARD DEVIATIONS OF MEDIAN
REACTION TIMES ON COGNITIVE TASK
(IN MILLISECONDS)

| Group | Left Visual Field | | | | Right Visual Field | | | |
|---|---|---|---|---|---|---|---|---|
| | Day 1 | | Day 2 | | Day 1 | | Day 2 | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Letters | | | | | | | | |
| I | 688.3 | 74.2 | 628.1 | 96.1 | 685.9 | 73.7 | 615.4 | 80.6 |
| II | 783.8 | 217.8 | 748.9 | 244.5 | 752.4 | 161.1 | 713.0 | 229.5 |
| III | 717.7 | 87.9 | 692.4 | 88.2 | 734.0 | 111.3 | 712.2 | 77.3 |
| IV | 794.6 | 319.6 | -- | -- | 807.4 | 299.6 | -- | -- |
| Symbols | | | | | | | | |
| I | 676.7 | 93.4 | 633.0 | 69.9 | 712.6 | 107.1 | 629.7 | 71.8 |
| II | 792.9 | 233.7 | 749.1 | 244.7 | 815.4 | 246.2 | 725.1 | 225.1 |
| III | 790.5 | 164.3 | 696.3 | 105.7 | 835.4 | 187.3 | 731.2 | 117.2 |
| IV | 847.6 | 307.3 | -- | -- | 912.8 | 374.2 | -- | -- |

TABLE 15

MEANS AND STANDARD DEVIATIONS OF ERRORS
ON COGNITIVE TASK

| Group | Left Visual Field | | | | Right Visual Field | | | |
|---|---|---|---|---|---|---|---|---|
| | Day 1 | | Day 2 | | Day 1 | | Day 2 | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Letters | | | | | | | | |
| I | 7.3 | 4.3 | 7.5 | 4.4 | 11.2 | 2.8 | 10.3 | 1.8 |
| II | 9.5 | 2.5 | 9.4 | 3.7 | 9.7 | 2.9 | 10.5 | 2.0 |
| III | 7.2 | 4.0 | 7.7 | 4.5 | 11.4 | 3.5 | 12.4 | 3.6 |
| IV | 11.4 | 5.3 | -- | -- | 12.7 | 4.7 | -- | -- |
| Symbols | | | | | | | | |
| I | 10.1 | 2.8 | 9.5 | 3.2 | 9.7 | 2.7 | 11.5 | 3.1 |
| II | 12.0 | 3.4 | 8.7 | 4.3 | 11.7 | 3.6 | 10.2 | 2.3 |
| III | 11.0 | 2.7 | 11.5 | 2.7 | 11.3 | 3.8 | 11.4 | 3.1 |
| IV | 12.5 | 2.7 | -- | -- | 12.2 | 2.7 | -- | -- |

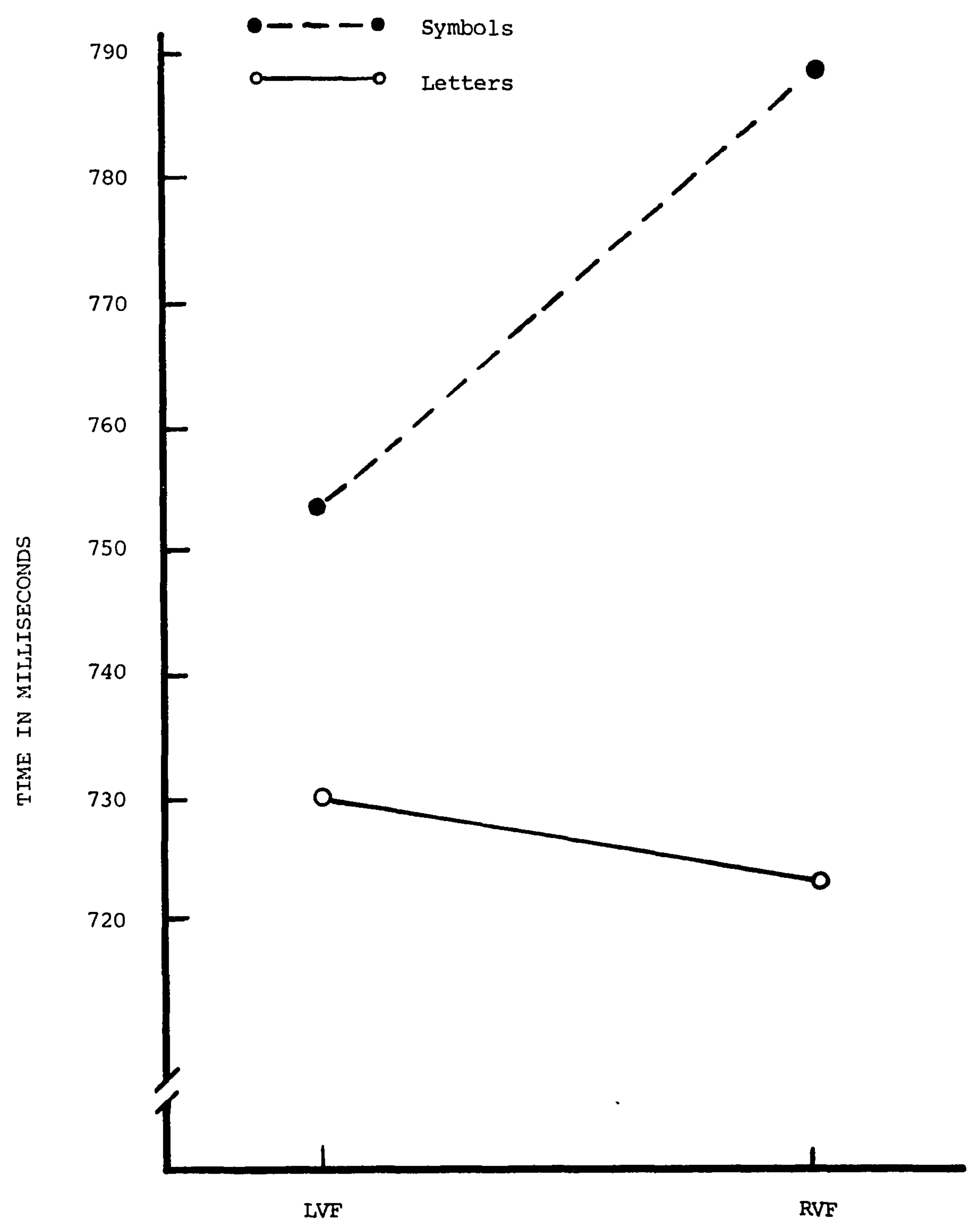


Figure 2. Means of median reaction times on the cognitive task on Day 1 (N = 30).

scores and showed a significant main effect for visual field ($F = 8.05$, $df = 1, 29$, $p < .01$), letter-symbol ($F = 12.60$, $df = 1, 29$, $p < .005$), and the visual field by letter-symbol interaction ($F = 10.16$, $df = 1, 29$, $p < .005$). The interaction effect is illustrated in Figure 3. It is now the symbols which fail to show visual field differences ($t < 1$, $df = 28$), while a marked difference occurs with the letters ($t = 4.13$, $df = 28$, $p < .001$). These results clearly support hypothesis b which stated that errors will be fewer for verbal stimuli than for novel non-verbal symbols. While no support is found for hypotheses e and f, surprisingly the VF difference for verbal errors is highly significant, but in opposite direction from the prediction! Errors for verbal stimuli are least in the LVF.

## Alcohol Effects

Blood alcohol concentration. Subjects in the alcohol groups began the cognitive task about 60 minutes after starting to drink, and 22 minutes from the completion of drinking (See Table 16). Subjects in the moderate dose group were tested on the ascending limb of the blood alcohol curve while those in the low dose group reached peak alcohol concentration during the task.

Reaction time. Examination of Table 14 indicates that reaction time of Group I (placebo) was 30 to 120 msec. faster than that of Groups II and III on Day 1, indicating that the random assignment of subjects to the experimental groups did not work with respect to reaction time. Since the placebo group is already faster than the two alcohol groups, a between-groups comparison of Day 2 (alcohol dose day) reaction times would be very

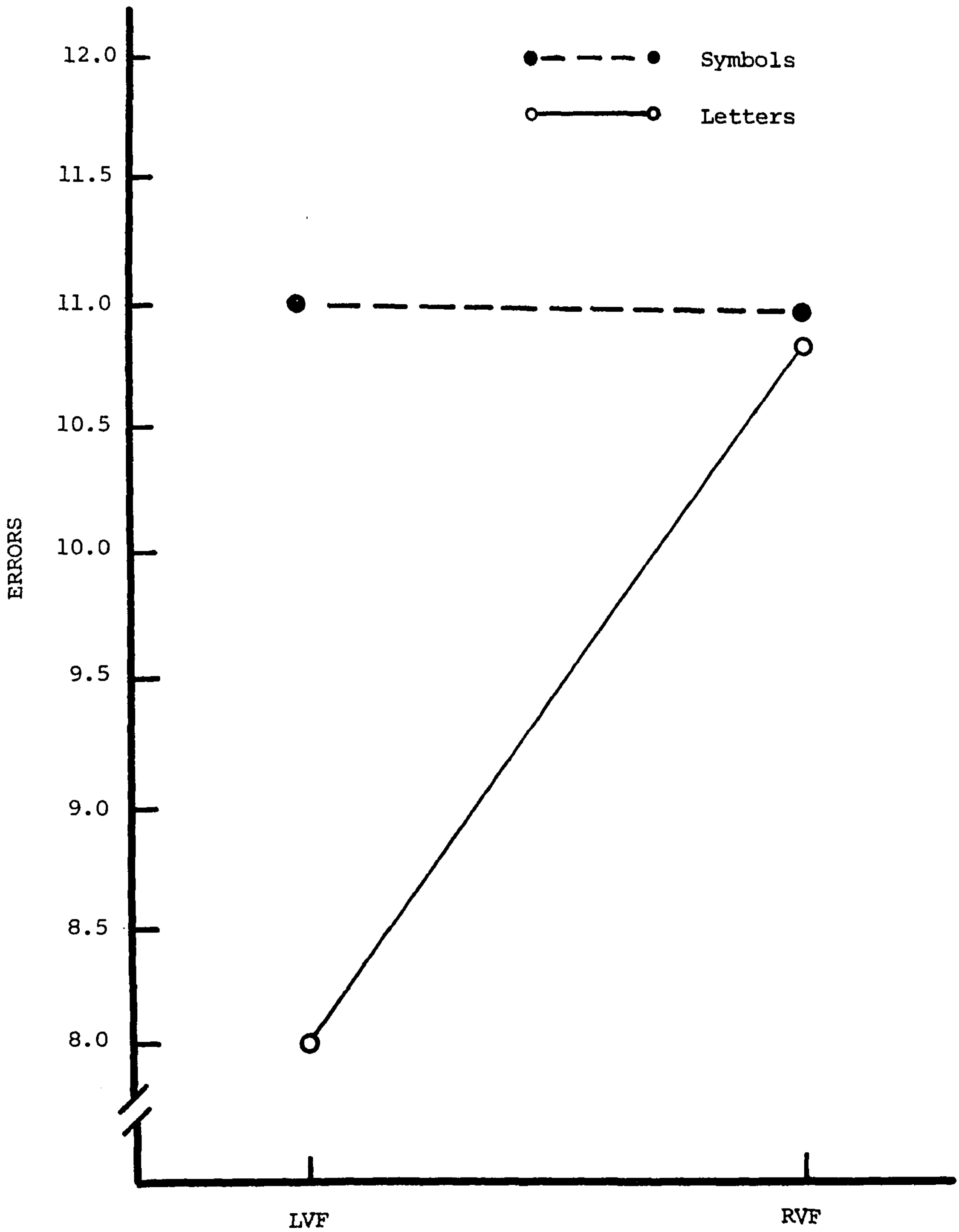


Figure 3. Mean number of errors on cognitive task on Day 1 (N = 30).

TABLE 16

MEANS AND STANDARD DEVIATIONS FOR TIME OF STARTING AND FINISHING COGNITIVE TASK AND BLOOD ALCOHOL CONCENTRATIONS (BAC)

| Group | | Time in Minutes* | | | | BAC (Mg. %) | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | Start | Middle | Finish |
| I | Mean | 55.10 | 24.30 | 12.80 | 80.20 | -- | -- | -- |
| | S.D. | 10.51 | 8.84 | 2.86 | 12.17 | -- | -- | -- |
| II | Mean | 59.50 | 22.80 | 12.50 | 89.10 | 45 | 50 | 53 |
| | S.D. | 9.80 | 5.16 | 2.99 | 10.80 | 12 | 9 | 9 |
| III | Mean | 60.90 | 21.30 | 14.00 | 89.50 | 84 | 86 | 94 |
| | S.D. | 8.50 | 3.89 | 2.36 | 10.90 | 16 | 13 | 16 |
| IV | Mean | 67.20 | 21.10 | 20.00 | 103.80 | 85 | 94 | 97 |
| | S.D. | 8.40 | 3.51 | 5.10 | 8.50 | 18 | 21 | 17 |

*1. From beginning of drinking to start of task

2. From finish of drinking to start of task

3. From start of task to middle of task BAC measure

4. From beginning of drinking to end of task

misleading, grossly exaggerating the effects due to alcohol. To correct for these large variations in baseline performance levels, a within-subjects, between-groups analysis of difference scores (Day 1 minus Day 2) was employed, using a 3 (groups) X 2 (visual field) X 2 (letter-symbol) mixed design analysis of variance (Lindquist, 1953).

A large practice effect is generally present in reaction time tasks, and is very evident in the Group I difference scores, being as large as 83 msec. for the RVF symbol mean. It should be noted that in a difference score analysis, the smaller positive, or larger negative difference values are those indicative of a detrimental alcohol effect.

The analysis of reaction time difference scores fails to yield a significant effect for alcohol ($F < 1$, df = 2, 27); hypothesis g is not supported. However, there is a significant within-subjects effect for visual field ($F = 4.25$, df = 1, 27, $p < .05$), indicating that more improvement was made in the RVF (68.2 msec.) than in the LVF (50.4 msec.). Though not achieving significance, reaction time to symbols improved more (76.5 msec.) than did reaction time to letters (42.1 msec.), ($F = 2.81$, df = 1, 27, p = NS). In answer to hypothesis g, no significant slowing of reaction time was found following administration of low and moderate doses of alcohol. As Tarter *et al.* (1971) have shown, on many tasks practice can mitigate the effects of alcohol.

*Errors*. The same 3 X 2 X 2 analysis of variance was applied to error rates and also fails to demonstrate a significant main effect for alcohol ($F = 2.31$, df = 2, 27, p = NS). Likewise, no significant differences were found in the amount of improvement occurring between symbol and letter stimuli ($F < 1$, df = 1, 27), or visual fields ($F = 1.79$, df = 1, 27, p = NS). In answer to hypotheses i and j, no significant decrease in response accuracy was found following ingestion of alcohol in either low or moderate doses.

Comparisons of Group IV, Day 1, with Group III, Day 2 (both had the same alcohol dose, but Group IV had no prior practice) show slower reaction times and more errors for Group IV, but these differences were not significant on the basis of simple t tests.

## Discussion

Before entering into a discussion of the results it seems appropriate to review some significant features of the nature and design of the cognitive task. The task assesses hemispheric functional asymmetry in the presence of bilateral simultaneous competing stimuli wherein the information presented in one VF must be inhibited while that in the opposite VF is to be processed. This design is unique amoung studies of hemispheric asymmetry. The design also differs from most others since it is a reaction time task and not a perceptual recognition task (as defined in Chapter I), thereby eliminating the possibility of a confounding verbal response. It also measures reaction times to physical identity matching of novel non-verbal stimuli in addition to the name identity matching of verbal stimuli. The design also permits the comparison of speed and accuracy at each level of processing.

### Hemispheric Functional Asymmetry

Reaction time. The data for the LVF are in general accord with neuropsychological theories which suggest that the right hemisphere is specialized for the processing of non-verbal stimuli requiring visuo-spatial analysis. Novel non-verbal symbols were processed more rapidly when they appeared in the LVF than in the RVF. These findings are congruent with those of Schell and Satz (1970) who found superior perception of non-verbal visual designs in the LVF; and Gibson, Filby and Gazzaniga (1970) who report a 14 msec. faster reaction time in the LVF on a task requiring the mental rotation and matching of two non-verbal figures, even though the response was a verbal one.

A RVF superiority was predicted when verbal stimuli (letters) were to be compared for having the same name, but this was not found. On the basis of the majority of studies cited in Chapter I which deal with interhemispheric visual differences, we would expect a very strong RVF advantage in the processing of verbal stimuli, especially the naming of such stimuli. That such was not found requires additional explanation.

Theories of neuropsychological function which assign all linguistic functions to the left hemisphere and hold the right hemisphere primarily responsible for non-verbal processing do not seem to be quite adequate in explaining the obtained lack of VF differences in the naming task. However, Bogen (1969) and Gazzaniga (1970) have each proposed a unique mode of information processing for the right hemisphere. Bogen has suggested that the right hemisphere acts as a "comparator" of schemas, engrams, perceptions, while in a similar fashion Gazzaniga refers to it as a "verifier" in which stimuli are held in reverberating circuits for sufficient time to "permit the system to check and re-check" the stimuli and "subsequently possibly to initiate qualifying remarks" about the attributes of the stimulus.

If the right hemisphere is specialized as a comparator or verifier, then we would expect little difference between visual fields in reaction time to verbal stimuli which must be compared for name. On such a task, the two hemispheres may work together, the right hemisphere performing the basic analysis of the physical aspects of the stimuli while the left does a linguistic analysis and search for the proper names to assign to the stimuli. The slight RVF advantage might be due to the stimulus arriving first at the left hemisphere where the presumably more time-consuming linguistic analysis is allowed a few msec. "lead time" as compared to a right hemisphere presentation. Additionally, the presence of the competing stimuli in the opposite VF may be more disruptive when the hemispheres are required to share the information processing load.

The LVF superiority in the processing of novel non-verbal symbols is expected from the neuropsychological studies, and this expectation is increased when we invoke the "comparator" function. Since the instructional set is for physical identity matching of only the novel non-verbal symbols, and if the right hemisphere is specialized for processing non-verbal stimuli <u>and</u> acting as a comparator of stimuli, then the total processing load is carried by one hemisphere and the resulting reaction time is faster. Such a position gains support from the work of Geffen, Bradshaw and Nettleton (1972) who suggest that the right hemisphere is better than the left in all types of physical identity matching. Likewise, Cohen (1972) and Gibson, Dimond and Gazzaniga (1972) have both reported LVF superiority for physical identity matching of letters and 3 or 4 letter nouns respectively.

The increase of 34.8 msec. in reaction time when non-verbal materials requiring visuospatial analysis are presented in the RVF may be the result of the transcallosal transmission of information, or it may reflect the less efficient, hence slower, processing of such stimuli by the left hemisphere. Geffen, Bradshaw and Wallace (1971) have argued that both of these factors are probably involved. However, it would seem that a parsimonious explanation would favor the transcallosal transmission idea, at least in the neurologically intact human.

In general, under conditions of bilateral competing stimuli, the reaction time results suggest that the type of task may be equally important, if not more important, than the type of stimulus in determining hemispheric functional asymmetry. When visuospatial analysis of visual patterns is required, the right hemisphere is better than the left. When a linguistic analysis of visual stimuli is required it appears that the two hemispheres may share the task, with the right performing a basic analysis of the physical features and/or the result of the linguistic analysis, and the left doing the basic linguistic analysis portion, with enough time lag to obscure the otherwise superior linguistic function of the left hemisphere.

Error rates. The results indicate that there is a large VF difference in error rates for verbal stimuli, the LVF having the lowest error score; while non-verbal stimuli show no VF differences in error scores. Again, the bulk of the perceptual recognition studies would lead us to predict just the opposite for verbal stimuli, but would concur with the non-verbal results.

The lack of VF differences for non-verbal errors could be attributed to the relatively low complexity of the stimuli. Several of the perceptual recognition studies (Terrace, 1959; Heron, 1957; Bryden and Rainey, 1963; Kimura, 1966; Fontenot, 1973) have failed to find VF differences in recognition errors for non-verbal materials, except where the stimuli consisted of highly complex designs.

Another explanation is that the stimuli are totally unfamiliar and hence "noise" in the processing system might degrade the stimulus trace more than would occur with such highly familiar stimuli such as letters. If stimulus degradation did occur, the novelty of the stimuli would prevent any attempt to "reinforce" or "repair" the stimulus trace prior to final analysis, whereas memory components could be activated to reinforce or repair familiar letter stimuli.

Sternberg (1969, pp. 434-435) has developed techniques which could be adapted to evaluate these ideas. By using test stimuli which have been "degraded" by specific amounts, e.g. 10%, 20%, 30%, etc., the role of memory components active in the repair or reinforcement process could be assessed across a range of stimuli such as (1) letters and nouns, (2) simple geometric designs which in themselves are non-verbal but have very familiar verbal labels (circle, square, etc.) and (3) unique, novel non-verbal designs which have no immediate verbal referent.

The unexpected finding of verbal errors being least in the LVF does not seem so surprising when viewed in light of Bogen's comparator function and the bilateral competing stimulus paradigm.

When bilateral competing stimuli are presented, the right hemisphere being more specialized for making comparisons does so with fewer errors than the left hemisphere; particularly when dealing with familiar stimuli such as letters. It should be remembered that when letters were appearing in the LVF non-verbal symbols were seen in the RVF. The left hemisphere being least equipped for the processing of non-verbal visuo-spatial stimuli, may not attempt to do so, leaving the letters in the right hemisphere to be processed without significant interhemispheric distraction or conflict. However, when letters appear in the RVF, and symbols are appearing in the LVF, the left hemisphere not being specialized for comparator functions, makes more errors, possibly due to the appearance of non-verbal stimuli in the right hemisphere which tend to be processed in spite of the instructional set.

## Alcohol Effects

The failure to find a significant slowing of reaction time following administration of either low or moderate doses of alcohol does not conform to the traditional view of alcohol as a debilitating beverage. Indeed, so many studies have reported a slowing of reaction time subsequent to alcohol ingestion that one is tempted to ask "Why do another study of reaction time and alcohol?" It appears evident from the present study that such generalizations are indeed generalizations, and do not always apply. The experimental design allowed a significant practice effect to operate, as seen in the performance of the placebo group. The low dose alcohol effect appears to have been an increase in reaction time variability, especially for verbal stimuli. The moderate dose group shows a marked decrease in reaction time variability except in the case of LVF letters. Response accuracy, as measured by the number of erros, seems generally unaffected by alcohol, at least in the doses used in this study.

In summary, some scattered evidence is indicative of an alcohol effect upon the cognitive task, but this effect is not a systematic one, and fails to attain statistical significance. It also appears that the effect of alcohol was, to a large extent, mitigated by the effects of practice.

# CHAPTER VI

## SUMMARY AND DISCUSSION

The present study examined some of the effects of low and moderate doses of ethyl alcohol upon human brain function with specific reference to differences in functional asymmetry of the cerebral hemispheres and the inhibitory capacity nature of the tasks used to sample the motor, sensory and cognitive aspects of CNS function. The tasks used to assess these functions required divided or selective attention to stimuli which presented similar, but not identical, information to the two cerebral hemispheres simultaneously.

In general, the literature of neuropsychology lends support to the concept of differential specialization of the two cerebral hemispheres in man. Studies of normal and brain-damaged persons both reveal significant evidence for a left hemisphere control of linguistic function (especially in right-handed individuals) and a right hemisphere mediation of non-linguistic and visuospatial functions. However, there have been very few neuropsychological studies relating the affects of acute alcohol ingestion to differential cerebral functioning in humans. Studies of chronic alcoholics suggest many similarities to the behavioral deficits exhibited by persons known to have damage to the right cerebral hemisphere. Other research indicates that alcoholics have a deficit in inhibitory motor control, although it is not known whether this deficit is merely a correlate of chronic alcoholism or the consequence thereof. The dissertation therefore investigated three general questions relative to the effects of low and moderate doses of alcohol. 1. Does acute alcohol intake affect the functions mediated by the right cerebral hemisphere more than those mediated by the left? 2. Does alcohol have differential effects as a function of the nature of the tasks, i.e., motor, sensory and cognitive? 3. Does alcohol produce a lower capacity for inhibitory motor control?

The alcohol effects were investigated using 40 male medical and graduate students who were randomly assigned to one of four treatment conditions: I, placebo-placebo; II, placebo- .88 ml. 95% USP ethanol/Kg. body weight; III, placebo- 1.32 ml./Kg. and IV, 1.32 ml./Kg. The placebo doses were administered on the first day of testing for subjects in Groups I-III and the alcohol dose or another placebo was given 24 hours later. Group IV received only the moderate alcohol dose. Each subject performed three types of experimental tasks, motor, sensory (auditory and visual), and cognitive.

The motor task investigated all three experimental questions and was the only task directed specifically toward evaluating changes in inhibitory motor control following acute ingestion of alcohol. In this task the subject was required to perform two different tasks simultaneously. The knob turning task required the subject to turn a knob 180° as slowly as possible consistent with continuous movement of the knob. At the same time the other hand was involved in a key pressing task requiring a completely different set of motor movements--sequentially depressing a set of four keys in a specific pattern and at a specific rhythm.

The results indicate that alcohol in low and moderate doses leads to lessened inhibitory control over slow motor movement in a knob turning task when subjects are required to perform two tasks simultaneously. The detrimental effects of alcohol were found in both the low and moderate alcohol dose groups, with larger deficits occurring in the moderate as compared to the low dose group on both knob errors and knob turning time. The deficits in inhibitory motor control as a function of alcohol showed no significant hemispheric lateralization effect. Key press performance did not seem to be affected in any consistent manner by alcohol, and no "trade-off", in which performance on one task is sacrificed in order to maintain performance on another, was found. While most alcohol experiments have concentrated on showing that speed of reaction is slowed, the present experiment has demonstrated that behavior at the other end of the scale is also affected.

In response to experimental questions 1, 2 and 3 alcohol was shown to have a detrimental effect on motor tasks, but this effect shows no differential hemispheric lateralization; and alcohol resulted in a lowered capacity for inhibitory motor control.

The auditory task was a dichotic stimulation task designed by Edelberg in which different patterns of Morse code type tones were simultaneously presented to the right and left ears. The subjects' task on a given trial was to manually report (by pressing one of five levers) the number of short tones heard in one ear while disregarding the conflicting set of tones heard in the other ear.

The visual task was similar to the auditory task, with the same tape-recorded signals which produced the tones now being used to control small indicator lamps placed 30$^{o}$ left and right of central binocular fixation. On a given trial, the subject was to orally report the number of short flashes of light appearing in one VF while maintaining central fixation and disregarding the visual signals in the opposite VF. Scoring on both tasks was in terms of the number of errors (incorrect responses) made.

Under placebo conditions, the results of the auditory task are congruent with Kimura's findings of better tonal pattern recognition in the left ear. Under alcohol dose the left ear errors increased slightly while right ear errors sharply decreased, suggesting a weak lateralized effect of alcohol upon the right hemisphere. These differences were not large enough to gain statistical support.

In the visual task high intra-group variability prevented the results from achieving significance. However, two observations were of interest. First, with placebo RVF errors were less than LVF errors, opposite of what was predicted; and second, the poorer performance in the RVF with the alcohol doses. Suggestions were made relating the placebo results to the verbal-mathematical superiority of the left hemisphere, and to Kinsbourne's attentional hypothesis of lateral specialization in the cerebral hemispheres. The overall lack of significant alcohol effects are probably best accounted for by Jones' (1972) finding that performance is much more disrupted on the ascending limb of the blood alcohol concentration curve than on the descending limb where the sensory tasks took place.

In answer to experimental questions 1 and 2, no significant alcohol effects were found on either the auditory or visual sensory tasks, precluding an evaluation of possible differential hemispheric lateralization of such effects.

The cognitive task experiment was designed to assess differences in hemispheric functional asymmetry, and also to evaluate the effects of low and moderate doses of alcohol upon the behaviors used in assessing such asymmetry. The task involved the tachistoscopic presentation of linguistic stimuli (letter pairs) to one VF simultaneously with non-linguistic stimuli (nonsense symbols) to the opposite VF. On a given block of trials the subject's task was to decide whether the letters had the same name or whether the nonsense symbols had the same shape. The subject's manual response time in milliseconds was measured by an electronic decade timer.

The placebo dose reaction times were used to assess hemispheric functional asymmetry. The data for the LVF was in accord with neuropsychological theories which suggest that the right hemisphere is specialized for the processing of non-verbal stimuli requiring visuospatial analysis, the reaction time to such stimuli being shorter when presented in the LVF than in the RVF. The predicted RVF superiority for verbal materials failed to occur, with reaction times to verbal stimuli being only minutely faster in the RVF than LVF. An analysis of the errors committed on the cognitive task reveals a large VF difference in error rates for verbal stimuli; the LVF being lowest; while no VF differences were found for non-verbal stimuli. The unexpected findings of very little VF differences in reaction time to verbal stimuli, and the large VF differences in error rates for verbal stimuli are not in accord with popular neuropsychological theory. The total pattern of results for the cognitive task for both reaction time and errors was interpreted in light of Bogen's hypothesized "comparator" function of the right cerebral hemisphere, whereby the type of information processing required is more important than the verbal-non-verbal nature of the stimuli to be processed.

No statistically significant changes were seen in cognitive function as a consequence of low or moderate doses of alcohol (Question 2). While alcohol effects were present, they did not seem to have any systematic effect upon behaviors sampled and there was evidence of the alcohol effects being mitigated by the effects of practice. Likewise, no differential hemispheric lateralization effects of alcohol were noted (Question 1).

Experimental question 2, "Does alcohol have differential effects as a function of the nature of the tasks, i.e., motor, sensory and cognitive?" can be evaluated by reviewing the results of the separate studies. These results suggest that alcohol is more likely to have a detrimental effect upon motor task performance than upon sensory or cognitive tasks. This is true even though the cognitive task used a rapid, coordinated motor response (manual choice reaction time) as a measure of cognitive function. The relative immunity of cognitive function to the effects of alcohol are in accord with Goldberg's (1943) finding of intellectual functions being less impaired by alcohol than either sensory of motor functions.

In summary, within the experimental paradigm using simultaneous bilateral competing tasks or stimuli, the ingestion of low or moderate doses of alcohol showed no systematic effects on sensory or cognitive functions, but produced a significant deficit in inhibitory motor control. The deficit was found to increase as a function of increasing blood alcohol concentration. The placebo dose analysis of hemispheric functional asymmetry suggests that verbal versus non-verbal distinctions between left and right hemisphere are but one dimension of hemispheric specialization, and that attention must be paid to the type of information processing required. Support is given to Bogen's hypothesis that the right cerebral hemisphere in man may be specialized for the comparing of stimuli.

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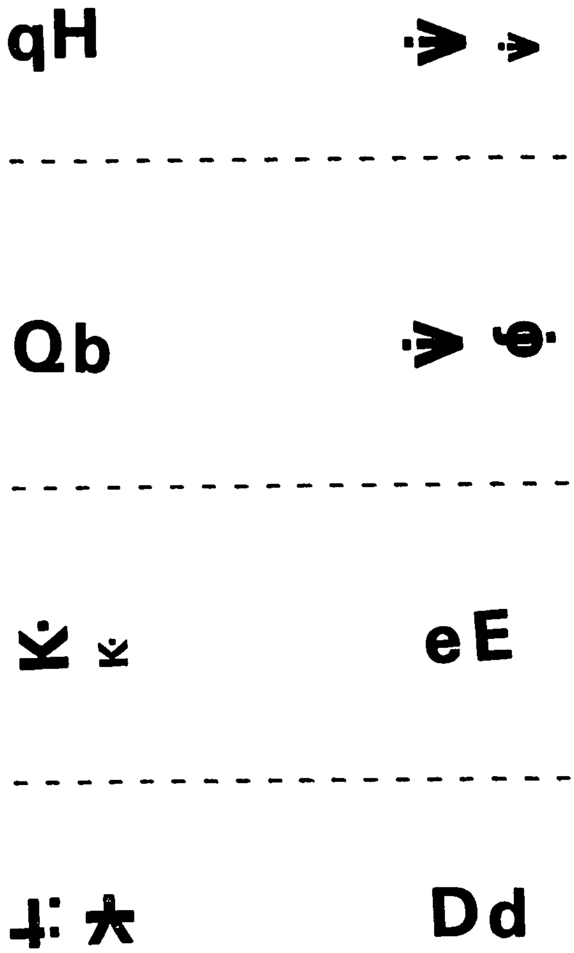
APPENDIX




Samples of typical stimuli used on the Cognitive task.

BLOOD ALCOHOL CONCENTRATIONS (Mg.%)

| | Measurement | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Group II | | | | | | |
| Subject | | | | | | |
| 1 | 20 | 50 | 70 | 60 | 50 | 50 |
| 2 | 50 | 50 | 50 | 50 | 50 | 50 |
| 3 | 50 | 50 | 40 | 50 | 40 | 40 |
| 4 | 50 | 40 | 60 | 50 | 50 | 50 |
| 5 | 50 | 50 | 60 | 60 | 50 | 40 |
| 6 | 60 | 60 | 50 | 50 | 70 | 50 |
| 7 | 50 | 60 | 60 | 50 | 50 | 50 |
| 8 | 50 | 50 | 50 | 40 | 50 | 50 |
| 9 | 30 | 30 | 40 | 40 | 40 | 40 |
| 10 | 40 | 60 | 50 | 50 | 50 | 30 |
| Group III | | | | | | |
| Subject | | | | | | |
| 1 | 100 | 90 | 80 | 90 | 90 | 80 |
| 2 | 60 | 60 | 90 | 90 | 90 | 70 |
| 3 | 80 | 80 | 80 | 80 | 80 | 80 |
| 4 | 80 | 90 | 100 | 100 | 100 | 90 |
| 5 | 90 | 100 | 110 | 120 | 120 | 110 |
| 6 | 90 | 100 | 110 | 110 | 110 | 110 |
| 7 | 80 | 80 | 90 | 100 | 100 | 80 |
| 8 | 90 | 90 | 90 | 100 | 100 | 90 |
| 9 | 60 | 70 | 70 | 80 | 80 | 60 |
| 10 | 110 | 100 | 120 | 110 | 120 | 100 |
| Group IV | | | | | | |
| Subject | | | | | | |
| 1 | 90 | 120 | 100 | 100 | 90 | 80 |
| 2 | 100 | 100 | 100 | 100 | 100 | 80 |
| 3 | 110 | 120 | 120 | 110 | 100 | 90 |
| 4 | 80 | 100 | 100 | 100 | 100 | 70 |
| 5 | 70 | 80 | 90 | 90 | 100 | 80 |
| 6 | 80 | 80 | 100 | 100 | 100 | 80 |
| 7 | 80 | 80 | 70 | 70 | 60 | 50 |
| 8 | 70 | 80 | 100 | 110 | 90 | 60 |
| 9 | 100 | 120 | 120 | 110 | 100 | 80 |
| 10 | 60 | 60 | 70 | 70 | 70 | 70 |

KNOB TURNING TASK--TIME AND ERRORS

| | Time (Seconds) | | | | Errors | | | |
|---|---|---|---|---|---|---|---|---|
| | Left Hand | | Right Hand | | Left Hand | | Right Hand | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group I | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 97 | 82 | 98 | 82 | 0 | 0 | 0 | 1 |
| 2 | 327 | 321 | 400 | 432 | 0 | 0 | 0 | 0 |
| 3 | 272 | 350 | 244 | 348 | 0 | 0 | 2 | 0 |
| 4 | 75 | 75 | 100 | 98 | 0 | 0 | 1 | 0 |
| 5 | 305 | 336 | 393 | 440 | 0 | 0 | 0 | 0 |
| 6 | 168 | 328 | 395 | 446 | 1 | 0 | 0 | 0 |
| 7 | 197 | 202 | 228 | 210 | 0 | 0 | 0 | 0 |
| 8 | 307 | 302 | 449 | 420 | 1 | 0 | 0 | 0 |
| 9 | 60 | 164 | 137 | 230 | 1 | 0 | 0 | 1 |
| 10 | 137 | 140 | 133 | 180 | 0 | 0 | 0 | 0 |
| Group II | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 138 | 100 | 122 | 111 | 1 | 2 | 2 | 3 |
| 2 | 119 | 163 | 124 | 179 | 0 | 0 | 0 | 0 |
| 3 | 117 | 116 | 126 | 82 | 0 | 2 | 0 | 1 |
| 4 | 258 | 223 | 410 | 359 | 1 | 0 | 0 | 1 |
| 5 | 234 | 178 | 330 | 261 | 0 | 0 | 0 | 1 |
| 6 | 202 | 154 | 193 | 182 | 0 | 0 | 1 | 0 |
| 7 | 243 | 237 | 192 | 205 | 0 | 0 | 0 | 0 |
| 8 | 233 | 132 | 230 | 155 | 0 | 0 | 0 | 0 |
| 9 | 164 | 182 | 223 | 202 | 1 | 3 | 0 | 1 |
| 10 | 221 | 138 | 275 | 198 | 0 | 2 | 2 | 1 |

KNOB TURNING TASK--TIME AND ERRORS

| | Time (Seconds) | | | | Errors | | | |
|---|---|---|---|---|---|---|---|---|
| | Left Hand | | Right Hand | | Left Hand | | Right Hand | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group III | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 54 | 45 | 76 | 67 | 1 | 0 | 0 | 0 |
| 2 | 131 | 104 | 115 | 79 | 0 | 0 | 0 | 3 |
| 3 | 89 | 117 | 131 | 112 | 0 | 0 | 1 | 0 |
| 4 | 359 | 260 | 236 | 317 | 1 | 5 | 0 | 3 |
| 5 | 970 | 674 | 977 | 666 | 0 | 7 | 0 | 3 |
| 6 | 193 | 97 | 214 | 135 | 0 | 2 | 0 | 0 |
| 7 | 363 | 328 | 587 | 446 | 0 | 0 | 1 | 1 |
| 8 | 44 | 66 | 68 | 152 | 0 | 0 | 0 | 1 |
| 9 | 133 | 140 | 192 | 188 | 0 | 0 | 0 | 2 |
| 10 | 267 | 118 | 359 | 190 | 0 | 1 | 0 | 3 |
| Group IV | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 177 | | 202 | | 0 | | 0 | |
| 2 | 115 | | 122 | | 0 | | 2 | |
| 3 | 266 | | 112 | | 3 | | 6 | |
| 4 | 47 | | 77 | | 3 | | 9 | |
| 5 | 364 | | 330 | | 0 | | 0 | |
| 6 | 201 | | 167 | | 0 | | 1 | |
| 7 | 263 | | 258 | | 0 | | 2 | |
| 8 | 181 | | 137 | | 4 | | 3 | |
| 9 | 571 | | 891 | | 1 | | 0 | |
| 10 | 104 | | 116 | | 3 | | 2 | |

KEY PRESS TASK--RATE PER SECOND AND ERRORS

| | Rate | | | | Errors | | | |
|---|---|---|---|---|---|---|---|---|
| | Left Hand | | Right Hand | | Left Hand | | Right Hand | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group I | | | | | | | | |
| Subject | | | | | | | | |
| 1 | .97 | 1.18 | 1.14 | .96 | 2 | 1 | 1 | 0 |
| 2 | 1.52 | .60 | 1.27 | .89 | 10 | 5 | 5 | 4 |
| 3 | 1.04 | .84 | .90 | .83 | 12 | 4 | 7 | 13 |
| 4 | 1.04 | .90 | 1.03 | .89 | 0 | 0 | 1 | 0 |
| 5 | .76 | .64 | .86 | .60 | 20 | 19 | 19 | 11 |
| 6 | 1.32 | 1.18 | 1.38 | .82 | 38 | 10 | 1C | 5 |
| 7 | 1.04 | .98 | .93 | .96 | 8 | 2 | 0 | 0 |
| 8 | 1.11 | .97 | 1.13 | .95 | 5 | 2 | 3 | 1 |
| 9 | 1.09 | 1.18 | 1.33 | 1.17 | 4 | 9 | 3 | 4 |
| 10 | 1.51 | 1.66 | 2.19 | 1.66 | 1 | 2 | 1 | 3 |
| Group II | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 1.16 | .89 | 1.14 | .77 | 9 | 8 | 4 | 7 |
| 2 | 1.31 | .78 | 1.37 | .96 | 8 | 14 | 7 | 10 |
| 3 | .76 | 1.60 | .78 | .66 | 4 | 7 | 1 | 3 |
| 4 | .79 | .93 | .81 | .86 | 23 | 25 | 13 | 9 |
| 5 | 2.23 | 2.48 | 2.35 | 2.48 | 21 | 26 | 8 | 4 |
| 6 | .84 | .71 | .86 | .78 | 0 | 22 | 1 | 0 |
| 7 | 1.02 | .87 | .90 | .91 | 3 | 4 | 6 | 0 |
| 8 | .56 | .85 | .60 | .72 | 4 | 4 | 1 | 0 |
| 9 | .85 | .95 | 1.04 | .88 | 16 | 19 | 13 | 14 |
| 10 | .83 | .94 | 1.38 | 1.11 | 18 | 3 | 3 | 11 |

KEY PRESS TASK--RATE PER SECOND AND ERRORS

| | Rate | | | | Errors | | | |
|---|---|---|---|---|---|---|---|---|
| | Left Hand | | Right Hand | | Left Hand | | Right Hand | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group III | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 1.67 | 1.58 | 1.69 | 1.67 | 5 | 15 | 1 | 2 |
| 2 | 1.00 | .82 | .97 | .73 | 4 | 7 | 4 | 4 |
| 3 | 1.00 | .84 | .99 | .90 | 19 | 19 | 19 | 15 |
| 4 | 1.04 | .77 | 1.09 | .76 | 8 | 5 | 16 | 1 |
| 5 | .78 | .50 | .37 | .51 | 20 | 11 | 9 | 6 |
| 6 | 1.54 | 1.38 | 1.46 | 1.44 | 9 | 11 | 83 | 21 |
| 7 | 1.03 | .70 | .98 | .80 | 29 | 2 | 15 | 5 |
| 8 | 2.94 | 2.16 | 1.93 | 2.11 | 5 | 19 | 11 | 4 |
| 9 | 1.05 | .77 | 1.05 | .60 | 7 | 3 | 11 | 0 |
| 10 | 1.33 | 1.05 | 1.45 | 1.18 | 16 | 16 | 6 | 3 |
| Group IV | | | | | | | | |
| Subject | | | | | | | | |
| 1 | .50 | | .69 | | 1 | | 1 | |
| 2 | .89 | | .87 | | 5 | | 2 | |
| 3 | .99 | | .90 | | 5 | | 6 | |
| 4 | 1.03 | | 1.11 | | 7 | | 3 | |
| 5 | .79 | | .80 | | 0 | | 3 | |
| 6 | .85 | | .90 | | 2 | | 0 | |
| 7 | .83 | | .84 | | 0 | | 3 | |
| 8 | 1.01 | | 1.14 | | 42 | | 36 | |
| 9 | .74 | | 1.00 | | 9 | | 14 | |
| 10 | .91 | | .88 | | 4 | | 7 | |

ERRORS ON SENSORY TASKS

| | Auditory Task | | | | Visual Task | | | |
|---|---|---|---|---|---|---|---|---|
| | Left Ear | | Right Ear | | LVF | | RVF | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group I | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 0 | 1 | 1 | 0 | 3 | 1 | 5 | 3 |
| 2 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 |
| 3 | 3 | 3 | 3 | 3 | 14 | 12 | 13 | 8 |
| 4 | 8 | 6 | 11 | 4 | 8 | 10 | 5 | 10 |
| 5 | 5 | 1 | 1 | 1 | 5 | 1 | 1 | 3 |
| 6 | 9 | 7 | 4 | 9 | 4 | 4 | 5 | 7 |
| 7 | 4 | 1 | 6 | 2 | 7 | 0 | 2 | 0 |
| 8 | 3 | 1 | 4 | 4 | 6 | 6 | 4 | 3 |
| 9 | 0 | 1 | 2 | 1 | 2 | 1 | 4 | 2 |
| 10 | 0 | 0 | 1 | 2 | 5 | 1 | 1 | 0 |
| Group II | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 1 | 4 | 1 | 2 | 1 | 9 | 1 | 8 |
| 2 | 2 | 3 | 5 | 1 | 4 | 1 | 2 | 0 |
| 3 | 2 | 9 | 7 | 5 | 10 | 4 | 4 | 6 |
| 4 | 2 | 1 | 2 | 2 | 3 | 0 | 2 | 2 |
| 5 | 3 | 4 | 3 | 2 | 6 | 4 | 4 | 5 |
| 6 | 10 | 6 | 4 | 4 | 4 | 13 | 4 | 7 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 8 | 2 | 0 | 1 | 1 | 2 | 1 | 1 | 1 |
| 9 | 3 | 2 | 2 | 2 | 4 | 8 | 7 | 8 |
| 10 | 2 | 4 | 5 | 2 | 14 | 7 | 11 | 6 |

ERRORS ON SENSORY TASKS

| | Auditory Task | | | | Visual Task | | | |
|---|---|---|---|---|---|---|---|---|
| | Left Ear | | Right Ear | | LVF | | RVF | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group III | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 1 | 3 | 3 | 1 | 5 | 2 | 5 | 4 |
| 2 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| 3 | 0 | 1 | 1 | 0 | 1 | 3 | 0 | 0 |
| 4 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| 5 | 2 | 3 | 0 | 1 | 4 | 4 | 4 | 2 |
| 6 | 5 | 6 | 7 | 2 | 9 | 7 | 6 | 7 |
| 7 | 2 | 1 | 2 | 0 | 2 | 4 | 2 | 2 |
| 8 | 2 | 2 | 7 | 3 | 5 | 3 | 2 | 2 |
| 9 | 9 | 2 | 7 | 3 | 0 | 1 | 2 | 3 |
| 10 | 8 | 7 | 8 | 5 | 10 | 9 | 9 | 11 |
| Group IV | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 14 | | 7 | | 10 | | 15 | |
| 2 | 1 | | 3 | | 3 | | 5 | |
| 3 | 7 | | 7 | | 5 | | 2 | |
| 4 | 3 | | 5 | | 4 | | 5 | |
| 5 | 2 | | 2 | | 0 | | 1 | |
| 6 | 1 | | 0 | | 2 | | 0 | |
| 7 | 6 | | 4 | | 6 | | 6 | |
| 8 | 13 | | 17 | | 11 | | 14 | |
| 9 | 1 | | 3 | | 6 | | 3 | |
| 10 | 1 | | 4 | | 1 | | 2 | |

MEDIAN REACTION TIME ON COGNITIVE TASK

(MILLISECONDS)

| | Letters | | | | Symbols | | | |
|---|---|---|---|---|---|---|---|---|
| | LVF | | RVF | | LVF | | RVF | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group I | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 752 | 818 | 743 | 788 | 703 | 789 | 731 | 668 |
| 2 | 597 | 516 | 580 | 530 | 589 | 567 | 627 | 581 |
| 3 | 636 | 610 | 635 | 600 | 742 | 652 | 764 | 719 |
| 4 | 599 | 551 | 608 | 630 | 732 | 614 | 756 | 577 |
| 5 | 730 | 572 | 740 | 522 | 842 | 642 | 860 | 652 |
| 6 | 802 | 623 | 788 | 563 | 619 | 602 | 696 | 611 |
| 7 | 644 | 582 | 648 | 605 | 615 | 546 | 611 | 543 |
| 8 | 728 | 774 | 770 | 701 | 688 | 617 | 665 | 599 |
| 9 | 761 | 644 | 716 | 638 | 722 | 701 | 876 | 770 |
| 10 | 634 | 591 | 631 | 577 | 515 | 600 | 540 | 577 |
| Group II | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 1011 | 1098 | 947 | 996 | 1001 | 952 | 1020 | 891 |
| 2 | 590 | 504 | 629 | 496 | 594 | 566 | 658 | 491 |
| 3 | 1161 | 1134 | 971 | 1146 | 1277 | 1269 | 1345 | 1169 |
| 4 | 624 | 641 | 608 | 617 | 607 | 539 | 621 | 543 |
| 5 | 789 | 614 | 860 | 639 | 708 | 890 | 629 | 883 |
| 6 | 735 | 721 | 776 | 679 | 959 | 820 | 925 | 819 |
| 7 | 713 | 481 | 673 | 515 | 775 | 532 | 906 | 549 |
| 8 | 519 | 527 | 519 | 434 | 532 | 488 | 532 | 467 |
| 9 | 643 | 786 | 632 | 733 | 614 | 655 | 662 | 642 |
| 10 | 1053 | 983 | 909 | 875 | 862 | 780 | 856 | 797 |

MEDIAN REACTION TIME ON COGNITIVE TASK

(MILLISECONDS)

| | Letters | | | | Symbols | | | |
|---|---|---|---|---|---|---|---|---|
| | LVF | | RVF | | LVF | | RVF | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group III | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 759 | 815 | 917 | 753 | 949 | 770 | 1013 | 888 |
| 2 | 819 | 780 | 728 | 745 | 679 | 565 | 704 | 579 |
| 3 | 711 | 646 | 752 | 734 | 598 | 582 | 620 | 626 |
| 4 | 826 | 758 | 876 | 754 | 1043 | 866 | 1234 | 879 |
| 5 | 810 | 755 | 842 | 731 | 1047 | 775 | 978 | 780 |
| 6 | 623 | 611 | 638 | 638 | 717 | 618 | 685 | 628 |
| 7 | 620 | 655 | 659 | 649 | 795 | 723 | 813 | 677 |
| 8 | 665 | 645 | 603 | 640 | 710 | 671 | 793 | 705 |
| 9 | 595 | 534 | 620 | 612 | 639 | 591 | 712 | 669 |
| 10 | 749 | 722 | 705 | 866 | 728 | 802 | 802 | 881 |
| Group IV | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 528 | | 548 | | 714 | | 727 | |
| 2 | 369 | | 385 | | 598 | | 507 | |
| 3 | 1071 | | 1088 | | 1161 | | 1551 | |
| 4 | 517 | | 567 | | 615 | | 575 | |
| 5 | 979 | | 1180 | | 857 | | 1088 | |
| 6 | 560 | | 631 | | 548 | | 604 | |
| 7 | 985 | | 872 | | 1035 | | 1163 | |
| 8 | 1415 | | 1299 | | 1523 | | 1447 | |
| 9 | 785 | | 710 | | 710 | | 714 | |
| 10 | 737 | | 794 | | 715 | | 752 | |

COGNITIVE TASK ERRORS

| | Letters | | | | Symbols | | | |
|---|---|---|---|---|---|---|---|---|
| | LVF | | RVF | | LVF | | RVF | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group I | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 6 | 9 | 13 | 11 | 7 | 9 | 6 | 7 |
| 2 | 13 | 8 | 11 | 6 | 12 | 11 | 11 | 14 |
| 3 | 6 | 6 | 7 | 9 | 12 | 9 | 11 | 14 |
| 4 | 5 | 16 | 12 | 13 | 10 | 14 | 9 | 10 |
| 5 | 5 | 2 | 9 | 14 | 8 | 8 | 10 | 7 |
| 6 | 4 | 3 | 11 | 9 | 6 | 9 | 5 | 10 |
| 7 | 9 | 7 | 9 | 4 | 10 | 9 | 8 | 10 |
| 8 | 16 | 12 | 13 | 13 | 10 | 11 | 13 | 13 |
| 9 | 2 | 3 | 10 | 8 | 10 | 11 | 12 | 14 |
| 10 | 7 | 9 | 17 | 8 | 16 | 12 | 12 | 16 |
| Group II | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 5 | 4 | 7 | 6 | 10 | 11 | 6 | 8 |
| 2 | 12 | 11 | 13 | 12 | 17 | 10 | 9 | 10 |
| 3 | 8 | 6 | 9 | 13 | 6 | 9 | 10 | 10 |
| 4 | 13 | 14 | 11 | 17 | 11 | 11 | 15 | 8 |
| 5 | 9 | 5 | 14 | 9 | 16 | 13 | 17 | 14 |
| 6 | 7 | 8 | 5 | 4 | 11 | 13 | 9 | 8 |
| 7 | 9 | 10 | 8 | 4 | 15 | 12 | 13 | 8 |
| 8 | 11 | 13 | 9 | 6 | 9 | 7 | 9 | 13 |
| 9 | 12 | 14 | 13 | 10 | 14 | 8 | 16 | 13 |
| 10 | 9 | 9 | 8 | 6 | 11 | 11 | 13 | 10 |

COGNITIVE TASK ERRORS

| | Letters | | | | Symbols | | | |
|---|---|---|---|---|---|---|---|---|
| | LVF | | RVF | | LVF | | RVF | |
| | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 | Day 1 | Day 2 |
| Group III | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 3 | 2 | 6 | 8 | 8 | 12 | 6 | 11 |
| 2 | 11 | 12 | 16 | 13 | 11 | 13 | 15 | 14 |
| 3 | 7 | 10 | 14 | 14 | 11 | 9 | 17 | 12 |
| 4 | 5 | 7 | 9 | 9 | 7 | 8 | 12 | 8 |
| 5 | 4 | 5 | 9 | 9 | 9 | 8 | 6 | 5 |
| 6 | 8 | 15 | 11 | 13 | 15 | 13 | 12 | 15 |
| 7 | 15 | 12 | 13 | 12 | 13 | 13 | 8 | 10 |
| 8 | 11 | 8 | 17 | 15 | 14 | 17 | 15 | 11 |
| 9 | 5 | 4 | 10 | 8 | 13 | 12 | 11 | 14 |
| 10 | 3 | 2 | 9 | 14 | 9 | 19 | 11 | 14 |
| Group IV | | | | | | | | |
| Subject | | | | | | | | |
| 1 | 15 | | 14 | | 16 | | 12 | |
| 2 | 17 | | 21 | | 11 | | 14 | |
| 3 | 7 | | 8 | | 10 | | 13 | |
| 4 | 16 | | 20 | | 13 | | 14 | |
| 5 | 7 | | 12 | | 7 | | 7 | |
| 6 | 7 | | 10 | | 13 | | 11 | |
| 7 | 3 | | 7 | | 12 | | 13 | |
| 8 | 10 | | 14 | | 15 | | 10 | |
| 9 | 13 | | 9 | | 13 | | 11 | |
| 10 | 19 | | 12 | | 15 | | 17 | |