HEMISPHERIC REACTIVITY TO BRIGHT LIGHT EXPOSURE: A TEST OF THE RELATIONSHIP BETWEEN AGE, HEMI-ACTIVATION AND DEPRESSION

by

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(ABSTRACT)

Much of the research on differential hemispheric activation as a function of age or the presence of depression suggests that a relative decrease in left hemisphere activation is associated with depression, while a decrease of right hemisphere activation is associated with age. Recent research, however, has demonstrated the role of the right hemisphere in maintaining general behavioral arousal. Pilot data suggest that elderly people experience behavioral over-arousal when presented with stressful or novel environmental stimuli. Equally interesting is the finding in a single-case study that ambient light and noise have a differential effect on behavior presumed to be representative of the left and the right cerebral hemispheres. The left hemisphere appears to be more responsive to ambient light level, with the right hemisphere being more responsive to ambient noise level. The present study sought to provide further support of selective hemispheric activation to bright light, and to examine the relationships among hemi-activation, age and depression by using behavioral measures of lateral anterior (finger tapping rate) and posterior (dichotic listening) cortical functioning. Two identical experiments were employed to evaluate old and young, and depressed and non-depressed subjects. Direct evidence of right hemi-aging effects on laterality was not significant in the first experiment, but data suggested the possibility of a ceiling effect for behavioral arousal in the older group which was not seen in younger subjects. The second experiment yielded no significant results between depressed and non-depressed groups. Hypotheses of under and over arousal in subjects are proposed to explain findings. Possible implications for treatment and recommendations for further research are proposed.

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Introduction

The hemi-aging hypothesis, that one hemisphere ages more quickly than the other, has been proposed from research on cognitive changes throughout the human life span, and most recently through investigations of changes in cortical hemisphere activation across ages. Similarly, studies of the neuropsychology of depression have supported the contention that the cerebral hemispheres are differentially activated during depression. Of particular interest are recent findings from our laboratory which suggest that ambient sensory conditions differentially affect lateralized behavior presumed to be due to activation of the lateral cerebral hemispheres. Given more data to support the possibility of selective activation during different sensory conditions, and a more complete understanding of the relationship between depression and laterality, the potential exists for environmental treatment strategies for disorders demonstrating a differential pattern of hemisphere activation.

Much of the literature concerning the neuropsychology of aging and affective disturbances uses the concept of cerebral asymmetry as a starting point. The finding that many motoric and sensory functions are controlled or processed in the contralateral hemisphere of the brain is basic to this type of investigation. However, cerebral asymmetry has also been found to extend to more complex functions such as the understanding of and production of language, the interpretation of visual/spatial information, the processing and interpretation of emotional stimuli and even the regulation of nervous system arousal (Kolb & Whishaw, 1990; Springer & Deutsch, 1989).

The left hemisphere has been shown to be most actively involved in the production and processing of verbal information, finely coordinated motor behavior, encoding of symbolic information, detailed analysis of stimuli, and time perception (Bryden, 1982; Kolb & Whishaw, 1990). Sensorimotor control of the distal parts of the right side of the body arises almost exclusively from the left hemisphere (Harrison, 1991; Kolb & Whishaw, 1990) and, generally speaking, images present in the right visual field and stimuli entering the right ear impinge on the left hemisphere (Kimura, 1967; Springer & Deutsch, 1989). Therefore, attention to and processing of elements in the right hemispace are governed to a large extent by the left hemisphere. Involvement of the left hemisphere in the processing or production of affective stimuli has been suggested within the context of approach/avoidance and cortical arousal conceptualizations. It has been suggested by several studies (Davidson, Schaffer & Saron, 1985; Geschwind, 1975; Malzman, Langdon, Pendery & Wolff, 1977) that approach behaviors involve well coordinated and sequenced actions, the production and interpretation of language, and fine motor coordination, all tasks which are said to be under primary control by the left hemisphere.

Aging and Lateralization

A number of studies have suggested that the right hemisphere develops at a more rapid rate than that of the left hemisphere (Davidson & Fox, 1989; Rothbart, Taylor & Tucker, 1989; Saxby & Bryden, 1985; Taylor, 1969). If, as has been suggested by these studies with infants and young children, the right hemisphere develops more quickly relative to the left hemisphere, it can be speculated that the right hemisphere might show signs of aging sooner. Additionally, studies suggest that women mature more rapidly than males, and such hemi-aging effects might be expected to manifest themselves sooner, and to a greater extent, in women.

A pattern of age related changes has been found in studies using a variety of laterality measures. For example, relative changes in hemispheric functioning have been demonstrated using data from intelligence tests (Stern, Oster and Newport, 1980), from neuropsychological test batteries (Klisz, 1978), and from cognitive measures (Elias, Winn & Wright, 1979). Botwinick (1977) found that elderly people experience a decrease in visuospatial functioning with no concurrent decrease in verbal processing ability. Although these studies typically have suggested a decrease with age in right hemisphere functioning, much of the data have been equivocal due to the possibility of verbal strategies for processing non-verbal material. Studies using behavioral measures to determine hemi-activation have provided more robust evidence of right hemi-aging. In 1987, Lapidot evaluated the hemi-aging hypothesis with a dual-task paradigm in which subjects were asked to maintain smooth pursuit eye movements (PEM's) while simultaneously performing verbal associations (producing a synonym for a word stimulus) or non-verbal imagery associations (describing a visual picture of the meaning of a word stimulus). Older subjects (60-73 years) experienced a greater number of tracking arrests (TA's) than the younger subjects (20-26 years). However, the older group experienced a significant increase in TA's during the non-verbal imagery association task, while the young subjects remained at the same level between conditions, suggesting decreased right hemisphere capacity to maintain the imagery task and PEM's simultaneously in older subjects.

Laterality studies of emotional processing suggest that the right hemisphere is involved with emotional processing in much the same way that the left hemisphere processes verbal information. Those with right parietal disease were found to have difficulty discriminating emotional tone from verbal content in speech in a 1977 study by Tucker, Watson and Heilman. Recent neuropsychological research on hemispheric processing of emotional information demonstrates a right hemisphere emphasis on interpretation and expression of affective information (Harrison, Gorelczenko & Cook, 1990; Harrison & Gorelczenko, 1991). Bunce and Harrison (1991) found that instructions given in child-directed speech, which was more melodic and emotionally expressive, were more effective for older adults than affectively neutral instructions. These data could be interpreted to support the idea of right hemisphere decline with age in that more expressive language (i.e., more stimulating to the right hemisphere) was required for better understanding in elderly subjects through arousal of right hemisphere tissue. Alden, Billings and Harrison (1991) found that while younger women experienced a negative affective bias to affect-neutral tachistoscopic faces projected to the right hemisphere, this bias was not found in the older women. A possible explanation of results included right hemisphere decrease in functioning with age.

The right cerebral hemisphere has been found to be involved in maintaining global cortical arousal levels (Heilman & Valenstein, 1979; Heilman & Van Den Abell, 1979). This suggests that the right hemisphere is more involved with escape behavior than the left, as it would be expected to activate the whole cortical network to act in a timely fashion. Heilman and Van Den Abell's (1979) study found that reaction times for warning stimuli presented to the right hemisphere were faster than for the same stimuli presented to the left hemisphere. If aging individuals experience a decrease in right hemisphere functioning, then an unstable pattern of emotional and autonomic reactivity to novel or stressful stimuli would be expected. In a 1988 study by Harrison and Edwards, elderly subjects were found to be more reactive (i.e. their blood-pressure increased) to having their blood-pressure measured than younger subjects. Harrison and Kelly (1989) found that an increase in ambient noise level resulted in significant increases in cardiovascular activity (i.e., systolic and diastolic blood pressure, and heart rate) in a group of elderly subjects which were not found in the group of young subjects. Increased reactivity in elderly subjects is also reflected in more behavioral laterality measures such has hand grip-strength. Zicafoose, et al. (1988) found that following the relocation of elderly inpatients, left hand grip strength increased significantly, while right hand strength remained consistent with pre-move levels. Additionally, this study found that the elderly group took longer to return to baseline than did the younger group.

In summary, there is evidence to support the hypothesis that elderly people experience a decrease in right hemisphere functioning. This decrease in functioning may be the factor responsible for the cardiovascular and cerebral reactivity with a slow habituation rate in older people which is generally not seen in younger people.

Depression and Cerebral Asymmetry

Early lesion studies found that left hemisphere damage resulted in dysphoric "catastrophic reactions" (Heilman & Satz, 1983; Ruckdeschel-Hibbard, Gordon & Diller, 1986). This phenomenon was also demonstrated through the anesthetic deactivation of the cerebral hemispheres using a fast-acting barbiturate (Wada test). In patients subjected to left hemisphere deactivation, the catastrophic-depressive reaction has most often been seen

(Heilman, Watson & Bowers, 1983; Kolb & Whishaw, 1990). Studies using electronic evaluation of brain activity also are suggestive of left hemisphere involvement in depression. For example, Davidson, Schaffer and Saron (1985) discriminated between subjects scoring high and those scoring low on the Beck Depression Inventory by using resting EEG power. The researchers found that the depressed subjects displayed a significant decrease in left frontal activation.

Behavioral performance tasks, such as dichotic listening and tachistoscopic tasks, have also implicated the left hemisphere in depression. For example, Johnson and Crockett (1982) and, Moscovitch, Strauss and Olds (1981) found that, on dichotic listening tasks, unipolar depressed subjects had a decreased right-ear advantage for verbal stimuli. The same subjects showed a reduced right-visual-field advantage for verbal stimuli presented tachistoscopically.

Ambient Stimuli Exposure and Cortical Arousal

In an early investigation into the cortical activating effects of ambient light exposure, Isaac (1960) found that cats exposed to increased illumination with noise had reaction times as fast as cats receiving direct electrical stimulation of the reticular formation in the absence of increased ambient sensory conditions. Later Kallman and Isaac (1977) demonstrated faster reaction times in humans responding to tactile stimulation under increased-intensity sensory conditions than in decreased-intensity conditions (again, sensory conditions were mixed combinations of light and noise level). Harrison, Kelly and Shapiro (1987), using variations of white noise intensity on older and younger women, found that both groups improved mathematical calculating ability with concomitant increases in ambient noise levels; however, the older group experienced a cardiovascular reactivity (increase) which was opposite to the effect on the younger subjects. Ambient light and noise level combinations were used in a single-case study of an elderly male with advanced dementia and excessive emotional vocalizations (Harrison, Lanter, Alden & Zicafoose, 1990). It was found that in bright light conditions, there was a reliable increase in the number of linguistic syllables expressed. It was also found that in the bright light conditions, the subject showed an increase in the duration of time spent orienting to the right hemispace. Conversely, in high noise conditions, the subject showed an increase in affective intensity and a decrease in the number of syllables expressed. In the high noise conditions the subject increased the amount of time orienting to the left hemispace. This fascinating effect, with the left hemisphere responding to non-sequential stimuli such as ambient light intensity, provides much of the motivation for the current study.

It should be noted that outside of literature in environmental psychology and general psychiatry, little work has been done strictly on the effect of light exposure on neuropsychological measures, and dependent variables in both these fields tend to be self-report or subjective measures of mood and/or performance. Previous experiments which were presented here involved collecting data during ambient noise/light combinations. One of the goals of this project was to quantitatively asses the effects of ambient light alone on behavioral neuropsychological measures.

Light exposure has been suggested for use in the treatment of depression in the psychiatry literature. Wehr et al. (1987), demonstrated a significant reduction of Hamilton Rating Scale scores in winter depression (i.e., Seasonal Affective Disorder) patients who received two four-hour light exposures for a period of seven days. Cited in this study are previous articles which demonstrated decreased depression measure scores with increased light exposure, and subsequent reversal of effects when the light exposure was discontinued (e.g. Hamilton scores increased following removal of the treatment). Meesters et al. (1991) found that using daily bright light exposure during the first signs of mood decrease in a population with a history of "winter depression" actually prevented the development of major depressive episodes when compared to no-treatment controls.

Boray, Gifford and Rosenblood (1989) investigated the possibility that full-spectrum light, which more closely matched the spectrum of natural sunlight, has a more pronounced effect on mood and cognitive performance. The results indicated that quantity of light was more important than quality, and that 40 watt cool-white, warm-white and full-spectrum fluorescent bulbs were equally effective at increasing arousal and pleasure scores on standardized self-report scales (Mehrabian & Russell's pleasure/arousal scales). More recently, Veitch, Gifford and Hine (1991) found demand characteristics to be the salient factor in producing differences in mood under cool-white versus full-spectrum light conditions rather than characteristics of the particular bulbs.

Sex Differences in Asymmetry

Early data on brain-injured individuals by McGlone (1978, 1980) found that men had more exclusively lateralized functioning, especially in language functioning, when compared to women. For example, men who suffered left hemisphere strokes with language deficits recovered little language functioning, whereas women with similar strokes recovered more. However, other studies using normal subjects have failed to reveal significant differences between sexes on behavioral tasks such as dichotic listening (Hiscock & McKay, 1985; Wexler & Lipman, 1988). A comprehensive review of verbal laterality studies found that women actually had a greater right-ear advantage for verbal stimuli in a dichotic paradigm than men in studies using normal subjects (Hiscock and Hiscock, 1988).

Although there are some data to suggest that women may be less strongly or extensively lateralized than men, the data seem equivocal. However, little data are available which support the opposite conclusion. Therefore, due to the limited number of elderly male subjects, and in order to control for sex differences in laterality, the present study used female subjects. It is thought that data collected could more logically be generalized from female to male populations than from male to female.

Current Investigation

The role of the right hemisphere in mediating cortical arousal levels, and the possibility that right hemisphere functioning declines with age has been suggested. It has also been pointed out that depressed subjects may demonstrate a decreased left hemisphere activation relative to the right hemisphere. Further, it has been demonstrated that the left hemisphere may be selectively activated by exposure to increased light intensity. This complex relationship between hemispheric activation and variables of depression, age and light intensity was investigated through two experiments. The first investigated the impact of light exposure on cerebral asymmetry in elderly and college-aged women, and examined the following hypotheses:

Hypotheses for Experiment 1

Finger Tapping Rate.

1. Older women will have a slower left hand relative to right hand tapping rate, when compared to younger women, due to right hemi-aging.

2. Both groups will experience a selective increase in right hand tapping rate in the bright light context due to selective activation of left hemisphere.

Dichotic Listening.

1. Older women will have an increased right ear advantage (REA), when compared to the younger women, due to right hemi-aging (i.e., decreased competition from the right hemisphere).

2. Older women will experience less attenuation of the REA during a focused-left condition due to hemi-inattention effects of right hemi-aging.

3. Older women will experience an increased REA during bright light context in a standard paradigm (non-focused) due to selective activation of the left hemisphere, relative to the younger group.

4. Older women will be better able to accentuate their REA during the focused-right condition and bright light context due to greater reactivity to light stimuli than younger women.

The second experiment investigated the extent of cerebral asymmetry and the impact of light exposure on laterality in depressed versus non-depressed college-age women, and examined the following hypotheses:

Hypotheses for Experiment 2

Finger Tapping Rate.

1. The depressed group will experience a poorer right hand tapping rate performance then the non-depressed group due to decreased left hemisphere activation.

2. The bright light context will increase the right hand rate in both groups, but the depressed group will experience a larger change between contexts due to lower base rate.

Dichotic Listening.

1. The depressed group will experience a smaller REA than the non-depressed group due to depression effects on left hemisphere cortex.

2. The depressed group will not accentuate the REA in the focused-right condition to the extent that the non-depressed group will.

3. The bright light context will increase REA in the depressed group by increasing left hemisphere activation.

4. The bright light context will increase the ability of the depressed group to accentuate the REA in a focused-right condition.

The driving theoretical positions behind the choices of measures in these two experiments bear some explanation. Since the hypotheses concern hemispheric lateralization, allowances were made to distinguish the lateralized cortical systems involved. A. R. R. Luria (1962/1966) suggested three functional systems within the central nervous system, two of which were cortical (affective and effective) and one subcortical (activating). The proposed experiments were designed to evaluate the system involving the affective to activating to effective/affective circuit which was more elegantly evaluated and expounded by

Heilman and Van Den Abell (1979). In their study, they suggested a cortico-thalamic-limbic loop which acts to maintain and modulate general cortical arousal levels. Therefore, in the present investigation, Teuber's "double dissociation principle" (1959) was incorporated to discriminate between cortical systems. To assess the effective (anterior cortex) systems, a simple finger-tapping rate task was used by virtue of the evidence supporting firm contralateral cortex support of more distal extremities (Heilman & Valenstein, 1985). To assess the affective or posterior cortex systems, a dichotic listening task was used by virtue of the hemispheric specialization for verbal processing, and the auditory extinction paradigm for detecting changes in cortical activation (Geffen & Quinn, 1984; Kimura, 1967; Springer & Deutsch, 1989).

Experiment 1

Method

Purpose.

The first experiment involved the examination of two groups of women to determine the presence of hemi-aging effects in performance, and was to determine the relative effects of light exposure on cerebral asymmetry between the two groups.

Subjects.

Subjects for the first study were 27 female college students from introductory psychology at Virginia Polytechnic Institute and State University included in the younger group, and 27 female volunteers recruited from the local community were included in the older group. All subjects were screened to exclude for neurological, auditory or visual impairment, and reading disability. A power analysis based on previous research using ambient sensory conditions to affect distal upper-extremity motor performance yielded an effect size (ES) of 1.08. Accepting an alpha level (a) of .05, and a power (b) of .95, and this estimated effect size, the prescribed number of subjects per group should be 26. Therefore, n for each of the groups (Old vs Young, & Depressed vs Non-depressed) was planned to be 26 (for more information on ANOVA power estimation, see Hays, 1988).

Apparatus: Experimental environment.

The study was conducted with the subject in a light-controlled area defined by the immediate vicinity of a desk and chair surrounded by flat white, opaque material. Light level was maintained at approximately 300 lux for the low light and pre-testing periods, and at a level of between 2000 and 2500 lux for the high light condition; three shop lights using two 40-watt Sylvania F40 rapid start bulbs each, and a ceiling-mounted light bank with two additional 40 watt Sylvania bulbs were used. Light levels were measured at the level of the subject's eyes and at a distance of 90 cm from the center of the light source using a Leitz hand held lux meter (see Appendices F and G).

Apparatus: Finger tapping rate.

Finger tapping was recorded using a single-throw key switch connected to a counting console consisting of two independent, high-speed, liquid crystal counting modules (Radio Shack 277-302), three silent pressure switches (single-pole, single-throw; 1-activate counter #1, 1-activate counter #2, 1-reset both counters; Radio Shack 275-1566), and a Lafayette Instrument Company Repeat Cycle Timer (5400-A) set to interval timing with 2x10 seconds. Event recording and monitoring was done outside of the subject's field of view, and soundless switches on the monitoring module and a quiet time-activated relay bank were used.

Apparatus: Dichotic listening.

Dichotic listening stimuli were 30 pairs of concurrently delivered (0 msec lag time) voiced consonant vowel (CV) syllables (ba, da, ga, ka, pa, and ta) on a computer-synthesized tape prepared at the Kresge Hearing Research Laboratory. Stimuli were presented at about 75 dB (A Scale) by a Magnavox AQ5090 dual-channel tape player using Koss K-6 stereo headphones. The interstimulus interval was approximately 6 seconds, and the CV syllables were presented in non-identical pairings. The six CV's were visually displayed for response identification as 2 cm. black upper-case letters on a 96 x 144 cm. index card in two rows of three pairs and displayed at a distance of about .5 m (see Appedix G, top view).

Measures: The Coren, Porac and Duncan Self-Report Lateral Preference Inventory.

This self-report inventory developed by Coren, Porac and Duncan (1979) demonstrates consistent right-side preferences by evaluating each of four domains: hand, eye, ear and foot preference. The authors reported that a score of at least +7 on this exam determines a right-side preference which supports inferences of left-hemisphere dominance (See Appendix B). Therefore, only those scoring a +7 or better were included in the study.

Measures: The Beck Depression Inventory.

The Beck Depression Inventory (BDI; Beck, et al., 1961) is a widely used depression measure (See Appendix C) designed to be a standardized measure of depression intensity useful for clinical and research purposes. It has been found to be a valid and reliable measure for use in general adult populations. In a comprehensive evaluation of numerous measures of depression, Rapp, Parisi, Walsh and Wallace (1988) found that a conventional BDI cutoff score of 10 had moderate sensitivity to depression, and had good negative predictive power (i.e. those scoring below this cutoff could confidently be called "non-depressed"). Due to the possible effects of affective state on hemispheric laterality, both young and old groups were given the BDI to account for differences.

Procedure

Screening and questionnaires.

The initial screening, testing and evaluation took place at the desk and chair provided for the subject. The subject was asked to sit in the chair in front of the desk, and then asked to read and sign the Informed Consent Form (see Appendix D). Information such as the name, age and birth date of the subject was garnered, along with any history of neurological, auditory or visual deficit. Subjects with a self-reported positive history of neurological dysfunction, hearing, visual or reading difficulty (exceptions being corrected vision or hearing) were excluded from the experiment. Next the examiner said, "I am going to ask you a series of questions. I want you to think about each question as if you were going to perform the task right here. Then answer using the words 'right', 'left' or 'either.' I will be standing behind you while you answer." Then the Self-Report Lateral Preference Inventory examination was administered orally, with the examiner out of the subject's visual field. Only subjects scoring +7 or better on this instrument were used for the study. Additional questions on family sinistrality were included (see Appendix E). Subjects unable to hear the questions while they are presented in a normal conversational level were excluded from the experiment. Next, the subject was asked to read the last line of the last page of text which was in front of them. Subjects unable to read the text at a rate of at least 100 words per minute were excluded from the experiment. The results of this initial interview and screening were recorded on the Data Collection Form (see Appendix E). Following the initial screening, the subject was told "I am going to leave for 3 minutes; when I return, we can begin." The examiner then set up the appropriate lighting conditions according to the counterbalancing table, and the subject was allowed to adapt to the conditions in the testing environment. The order of levels of the testing environment (i.e. bright light condition vs. low light condition) was counterbalanced between subjects. Similarly, the order of administering the following tasks was counterbalanced across subjects.

Experimental design.

Two age groups were used, a younger group and an older group. Each of these groups was exposed to a bright-light context and a low-light context. Within each context, the subjects were tested with a dichotic listening task with focused and non-focused conditions, and with a finger-tapping task. In the dichotic listening task, the order of testing non-focused and focused conditions was counterbalanced between subjects and within each context (see Appendix A). For the finger-tapping task, the order of testing left hand and right hand was counterbalanced between subjects and within each context.

Finger tapping rate task.

For the finger-tapping task, the subject was asked to close her hand into a fist, and to tap a key oriented at the subject's midline with their index finger using only a finger motion. Both of the subject's arms were resting on the desk. In the initial training phase, the subject was asked to practice with both hands until coordinated and rapid performance was obtained.

Once the subject had achieved rapid and accurate performance with each hand, the examiner said "When I say 'begin' I want you to tap as quickly as possible until I tell you to stop. Ready? Begin." Following a 5 second delay, a counter was activated automatically, and data were gathered for 20 seconds. Tapping was then discontinued.

The order of testing left hand, right hand was counterbalanced between subjects within each context. Additionally, the context order was counterbalanced between tasks (see Appendix A).

Dichotic listening task.

Three sets of 30 CV trials were given with the headphone placement (i.e., right and left speakers) altered across subjects. First the card containing the phonemes was placed in front of the subject, and the following instructions given: "You are going to put on these headphones, and when the tape begins, you will hear two sounds. One sound will come in one ear, and a different sound will come in the opposite ear. It will be like two people talking to you at the same time. I want you to tell me exactly what you hear. The way in which you will tell me what you hear is with your right hand, point to the sound you hear on the chart. Then take your hand away and look up at the curtain in front of you. Do you have any questions? [pause to answer questions] There will be a few instructions at the beginning of the tape and then it will start. You may put on the headphones." After the subject put on the headphones, the examiner started the tape, and stood behind and at the subject's midline.

After the first set of phonemes was finished, the tape was turned off, the card changed, and the subject was asked to remove the headphones for new instructions. "This time I want you to listen only to your left ear. Tell me exactly what you hear out of your left ear." These instructions were accompanied by a prompt, the examiner touching the left ear of the subject. The headphones were put on again, and the tape was turned on. Following the second set of phonemes, the tape was stopped, the earphones removed, and more instructions were given. "This time listen to your right ear only. Tell me exactly what you hear out of your right ear." These instructions were accompanied by a prompt, the examiner touching the right ear of the subject. The headphones were put on again, and the tape turned on. Following the third presentation, the headphones and the card were removed.

The order of testing dichotic listening in the non-focused condition, the focused left condition, and the focused right condition was counterbalanced between subjects within contexts. Similarly, the context was counterbalanced across subjects (see Appendix A).

Data analysis of results.

The first study was designed to address the general hypothetical questions: Does age affect lateralization? and does sensory context interact with age? Dichotic listening data were composed of raw data (i.e. correctly identified right ear stimuli, and correctly identified left ear stimuli) and were analyzed using a four factor mixed design, with repeated measures on context (Bright and Dim), Condition (Non-Focused, Focused-Left, Focused-Right), ear (Right and Left) and Subject. The finger-tapping rate data were composed of raw data (i.e. number of taps measured with each hand) analyzed with a three factor mixed design, with repeated measures on context (Bright and Dim), Effector (Left Hand and Right Hand), and Subject.

Proper use of the repeated measures or other ANOVA assumes homogeneity of variance between experimental groups (Hays, 1988). Therefore, all data were evaluated for this criterion. Dichotic listening data met the criterion; however, tapping rate data did not. A data transformation using the following formula was implemented prior to analysis: $\sqrt{x+1}$.

Results

Group Characteristics and Controls

The average age of the old group was 72 years (SD = 4.9), and the average age of the young group was 20 (SD = 4.1). The older group's average BDI score was 4.6 (SD=2.8) and the younger group's was 4.0 (SD=2.8).

Since ambient light conditions and seasonal changes in environmental light level were considered hypothetical variables in this study, possible differences in performance between months and times of day were evaluated. No significant differences in the dichotic listening data were detected between three months' of data gathering, $F(2, 51) = 0.90$, $p < 0.412$, or between three time periods during the day (i.e., morning, afternoon, evening), $F(2, 51) = 0.02$, $p < 0.98$. No significant inter-examiner differences were detected, $F(2, 51) = 1.46$, $p < 0.242$. Identical control analyses were performed for the tapping rate data; no significant seasonal, $F(2, 51) = 1.50$, $p < 0.155$, daily, $F(2, 51) = 2.61$, $p < 0.083$, or examiner, $F(2, 51) = 1.26$, $p < 0.293$ effects were detected.

Tapping Rate Data

The first analysis evaluated the hypothesis that the older group would have slower left hand relative to right hand tapping rate when compared to the younger group. Indeed, the difference between the right and left hand rate for the older women was less than that of the younger group (see Fig 1), but the difference was not statistically significant in the effector x group interaction, $F(1, 52) = 0.05$, $p < 0.824$.

Both groups were expected to experience a selective increase in the right hand tapping rate in the bright light context with little or no change expected in the left hand tapping rate. Interestingly, the older group experienced virtually no change in tapping rate in either hand between conditions, while the younger group left and right hand rates approached each other (see Figure 2). A main effect for groups was expected, but found to be non-significant, $F(1, 52) = 2.98$, $p < 0.09$, and the test for context effects between groups and hands (i.e., context x hand x group) was not significant, $F(1, 52) = 2.28$, $p < 0.137$.

Insert Figure 1 Here

Insert Figure 2 Here

Dichotic Listening Data

The first analysis evaluated the hypothesis that older women would evidence a greater relative right-ear advantage (REA) for dichotic syllables than younger women. In the normal or "dim" light condition, the younger women actually evidenced a greater REA; however, the differences in the rate of correct responding with either ear between groups was not significant, $F(1, 52) = 0.31$, $p < 0.58$ (see Figure 3). Therefore, the first hypothesis was not supported.

Older women were expected to show less attenuation of the REA during the focused-left condition. In fact, while the younger group was able to shift attention to the left ear such that it exceeded responding to the right ear (i.e., LEA), the older group data in this condition virtually mirrored that of the non-focused condition (see Figure 4). The difference between groups in the analysis of the group by condition interaction was significant, $F(2, 104) = 8.55$, $p < .001$.

The third hypothesis, that older women would experience an increased REA in the bright light context compared to the dim light context, was not supported by the data. In fact, the older group experienced little change between contexts, and the younger group only a mildly increased REA which was not statistically significant (see Figure 5). The group by context interaction was not significant, $F(1, 52) = 2.42$, $p < 0.126$.

The fourth hypothesis regarding dichotic listening effects, that older women would better increase their REA compared to younger women in the focused-right condition, bright light context due to increased reactivity, was not supported by the data. Between contexts, the older group's response characteristics were virtually unchanged, and the younger group increased the REA only minimally (see Figure 6). The group by condition by context interaction was not significant, $F(2, 104) = 0.11$, $p < 0.900$.

Insert Figure 3 Here

Insert Figure 4 Here

Insert Figure 5 Here

Insert Figure 6 Here

In summary, only the second dichotic listening hypothesis, that older women would show less attenuation of the REA during the focused-left condition than the younger women was supported by the data. In general the data changed little between contexts and conditions in the older group, while the younger group effectively changed their attention and reacted to changes in light context.

Post-Hoc Analyses

In order to fully evaluate the data in this experiment, further analyses were run. Since the dichotic listening task is essentially an extinction task with the possibility of selecting a stimulus CV which was not presented, an analysis of the error rate for each group was run. Consistent with the hypothesis proposed originally is that error rates would increase as hemi-activation decreased; therefore, the older women would be expected to make more errors in left ear stimuli than right. In fact, a main effect for groups was detected for error rate, $F(1, 52) = 17.77$, $p < 0.0001$, and the group by condition interaction was significant, $F(2, 104) = 8.55$, $p < 0.0004$. A contrast analysis revealed that the focused right condition within the young group produced significantly more errors than the other two conditions, $F(1, 52) = 14.38$, $p < 0.0004$. This is an interesting contrast to the older group who showed no significant difference in error rate between contexts and conditions (see Figure 12).

Such a significant difference between old and young groups on error rate production during the dichotic listening task could have influenced the results of the original analyses; therefore, the data were thinned out to contain only those records containing at least 75% correct responses on all trials. This resulted in the loss of only 11 total subjects. The results of the analysis with 75% correct data were virtually identical to those of the original data set.

Experiment 2

Method

Purpose.

The second experiment involved the examination of two groups of women to determine the presence of depression effects in performance, and to determine the relative effects of light exposure on laterality between the two groups.

Subjects.

Subjects for the second study were 42 female college students from introductory psychology at Virginia Polytechnic Institute and State University divided into two 21-subject groups according to a pre-defined cutoff score on the Beck Depression Inventory (BDI). Potential subjects were chosen following group testing with the BDI, and those chosen for either the depressed or non-depressed groups were tested again prior to participation in the lab to verify a consistent affective state. All subjects were screened to exclude for neurological, auditory or visual impairment, and reading disability. A power analysis based on previous research using ambient sensory conditions to affect distal upper-extremity motor performance yielded an effect size (ES) of 1.08. Accepting an alpha level (a) of .05, and a power (b) of .95, and this estimated effect size, the prescribed number of subjects per group should be 26. Therefore, n for each of the groups (Old vs Young, & Depressed vs Non-depressed) was planned to be 26 (for more information on ANOVA power estimation, see Hays, 1988).

Apparatus: Experimental environment.

The study was conducted with the subject in a light-controlled area defined by the immediate vicinity of a desk and chair surrounded by flat white, opaque material. Light level was maintained at approximately 300 lux for the low light and pre-testing periods, and at a level of between 2000 and 2500 lux for the high light condition; a total of three shop lights using two 40-watt Sylvania F40 rapid start bulbs each, and a ceiling-mounted light bank with two additional 40 watt Sylvania bulbs were used. Light levels were measured at the level of the subject's eyes and at a distance of 90 cm from the center of the light source (see Appendices F and G).

Apparatus: Finger tapping rate.

Finger tapping was recorded using a single-throw key switch connected to a counting console consisting of two independent, high-speed, liquid crystal counting modules (Radio Shack 277-302), three silent pressure switches (single-pole, single-throw; 1-activate counter #1, 1-activate counter #2, 1-reset both counters; Radio Shack 275-1566), and a Lafayette Instrument Company Repeat Cycle Timer (5400-A) set to interval timing with 2x10 seconds. Event recording and monitoring was done outside of the subject's field of view, and soundless switches on the monitoring module and a quiet time-activated relay bank were used.

Apparatus: Dichotic listening.

Dichotic listening stimuli were 30 pairs of concurrently delivered (0 msec lag time) voiced consonant vowel (CV) syllables (ba, da, ga, ka, pa, and ta) on a computer-synthesized tape prepared at the Kresge Hearing Research Laboratory. Stimuli were presented at about 75 dB (A Scale) by a Magnavox AQ5090 dual-channel tape player using Koss K-6 stereo headphones. The interstimulus interval was approximately 6 seconds, and the CV syllables were presented in non-identical pairings. The six CV's were visually displayed for response identification as 2 cm. black upper-case letters on a 96 x 144 cm. index card in two rows of three pairs and displayed at a distance of about .5 m (see Appedix G, top view).

Measures: The Coren, Porac and Duncan Self-Report Lateral Preference Inventory.

This self-report inventory developed by Coren, Porac and Duncan (1979) demonstrates consistent right-side preferences by evaluating each of four domains: hand, eye, ear and foot preference. The authors report that a score of at least +7 on this exam determines a right-side preference which supports inferences of left-hemisphere dominance (See Appendix B). Therefore, only those scoring a +7 or better were included in the study.

Measures: The Beck Depression Inventory.

The Beck Depression Inventory (BDI) is a widely used depression measure (See Appendix C) designed to be a standardized measure of depression intensity useful for clinical and research purposes. It has been found to be a valid and reliable measure for use in general adult populations. In a comprehensive evaluation of numerous measures of depression, Rapp, Parisi, Walsh and Wallace (1988) found that a conventional BDI cutoff score of 10 had moderate sensitivity to depression, and had good negative predictive power (i.e. those scoring below this cutoff could confidently be called "non-depressed"). Due to the possible effects of affective state on hemispheric laterality, both young and old groups were given the BDI to account for differences.

Procedure

Screening and questionnaires.

The initial screening, testing and evaluation took place at the desk and chair provided for the subject. The subject was asked to sit in the chair in front of the desk, and then asked to read and sign the Informed Consent Form (See Appendix D). Information such as the name, age and birth date of the subject was garnered, along with any history of neurological, auditory or visual deficit. Subjects with a self-reported positive history of neurological dysfunction, hearing, visual or reading difficulty (exceptions being corrected vision or hearing) were excluded from the experiment. Next the examiner said, "I am going to ask you a series of questions. I want you to think about each question as if you were going to perform the task right here. Then answer using the words 'right', 'left' or 'either.' I will be standing behind you while you answer." Then the Self-Report Lateral Preference Inventory examination was administered orally, with the examiner out of the subject's visual field. Only subjects scoring +7 or better on this instrument were used for the study. Additional questions on family sinistrality were included (see Appendix E). Subjects unable to hear the questions while they are presented in a normal conversational level were excluded from the experiment. Next, the subject was asked to read the last line of the last page of text which was in front of them. Subjects unable to read the text at a rate of at least 100 words per minute were excluded from the experiment. The results of this initial interview and screening were recorded on the Data Collection Form (See Appendix E). Following the initial screening, the subject was told "I am going to leave for 3 minutes; when I return, we can begin." The examiner then set up the appropriate lighting conditions according to the counterbalancing table, and the subject was allowed to adapt to the conditions in the testing environment. The order of levels of the testing environment (i.e. bright light condition vs. low light condition) were counterbalanced between subjects. Similarly, the order of administering the following tasks were counterbalanced across subjects.

Experimental design.

Two groups of subjects were used, divided into depressed and non-depressed groups according to the BDI cutoff score. Each of these groups was exposed to a bright-light context and a dim-light context. Within each context, the subjects were tested with a dichotic listening task with focused and non-focused conditions, and with a finger-tapping task. In the dichotic listening task, the order of testing non-focused and focused conditions was counterbalanced between subjects and within each context. For the finger-tapping task, the order of testing left hand first and right hand first was counterbalanced between subjects and within each context (see Appendix A).

Finger tapping rate task.

For the finger-tapping task, the subject was asked to close her hand into a fist, and to tap a key oriented at the subject's midline with their index finger using only a finger motion. Both of the subject's arms were resting on the desk. In the initial training phase, the subject was asked to practice with both hands until coordinated and rapid performance was obtained.

Once the subject had achieved rapid and accurate performance with each hand, the examiner said "When I say 'begin' I want you to tap as quickly as possible until I tell you to stop. Ready? Begin." Following a 5 second delay, a counter was activated automatically, and data were gathered for 20 seconds. Tapping was then discontinued.

The order of testing left hand, right hand was counterbalanced between subjects within each context. Additionally, the context order was counterbalanced between tasks (see Appendix A).

Dichotic listening task.

Three sets of 30 CV trials were given with the headphone placement (i.e., right and left speakers) altered across subjects. First the card containing the phonemes was placed in front of the subject, and the following instructions given: "You are going to put on these headphones, and when the tape begins, you will hear two sounds. One sound will come in one ear, and a different sound will come in the opposite ear. It will be like two people talking to you at the same time. I want you to tell me exactly what you hear. The way in which you will tell me what you hear is with your right hand, point to the sound you hear on the chart. Then take your hand away and look up at the curtain in front of you. Do you have any questions? [pause to answer questions] There will be a few instructions at the beginning of the tape and then it will start. You may put on the headphones." After the subject put on the headphones, the examiner started the tape, and stood behind and at the subject's midline.

After the first set of phonemes was finished, the tape was turned off, the card changed, and the subject was asked to remove the headphones for new instructions. "This time I want you to listen only to your left ear. Tell me exactly what you hear out of your left ear." These instructions were accompanied by a prompt, the examiner touching the left ear of the subject. The headphones were put on again, and the tape was turned on. Following the second set of phonemes, the tape was stopped, the earphones removed, and more instructions were given. "This time listen to your right ear only. Tell me exactly what you hear out of your right ear." These instructions were accompanied by a prompt, the examiner touching the right ear of the subject. The headphones were put on again, and the tape turned on. Following the third presentation, the headphones and the card were removed.

The order of testing dichotic listening in the non-focused condition, the focused left condition, and the focused right condition was counterbalanced between subjects within contexts. Similarly, the context was counterbalanced across subjects (see Appendix A).

Data analysis of results.

The second study addressed the hypothetical questions: Does depression affect lateralization? and does sensory context interact with depression? Dichotic listening data were composed of raw data (i.e. correctly identified right ear stimuli, and correctly identified left ear stimuli) and were analyzed using a four factor mixed design, with repeated measures on context (Bright and Dim), Condition (Non-Focused, Focused-Left, Focused-Right), ear (Right and Left), and Subject. The finger-tapping rate data were composed of raw data (i.e. number of taps measured with each hand) analyzed with a three factor mixed design, with repeated measures on context (Bright and Dim), Effector (Left Hand and Right Hand), and Subject. Proper use of the repeated measures or other ANOVA assumes homogeneity of variance between experimental groups (Hays, 1988). Therefore, all data were evaluated for this criterion. Dichotic listening data met the criterion; however, tapping rate data did not. A data transformation using the following formula was implemented prior to analysis: $\sqrt{x+1}$.

Results

Group Characteristics and Controls

The average BDI score of the depressed group was 13.5 (SD = 6.20), and the average BDI score of the non-depressed group was 3.5 (SD = 3.72). The depressed group average age was 17.9 (SD = 4.88), and the non-depressed group's was 17.6 (SD = 4.61).

Since ambient light conditions and seasonal changes in environmental light level are considered hypothetical variables in this study, possible differences in performance between months and times of day were evaluated. No significant differences in the dichotic listening data were detected between four months' of data gathering, $F(3, 38) = 0.75$, $p < 0.530$, or between three time periods during the day (i.e., morning, afternoon, evening), $F(2, 39) = 1.07$, $p < 0.352$. A significant inter-examiner effect was noted in this experiment, $F(4, 37) = 2.97$, $p < 0.03$, and a contrast analysis revealed that data from examiner number 4 were unusable. However, this examiner only ran one subject, and a direct examination of data collection protocols for this subject revealed numerous errors. When this subject's data were removed from the analysis, no examiner effects remained. Identical control analyses were performed for the tapping rate data; no significant seasonal, $F(2, 38) = 0.53$, $p < 0.921$, daily, $F(2, 38) = 1.01$, $p < 0.373$, or examiner, $F(3, 37) = 0.07$, $p < 0.977$ effects were detected.

Tapping Rate Data

The depressed group was expected to have a slower general finger tapping rate due to decreased cortical activation with a particular effect on the right hand due to the hypothesized decrease in left hemisphere functioning with depression. The depressed group actually had an increased right hand tapping-rate in the dim or normal light context (see Figure 7), yet the difference was within that expected by chance alone. The difference between groups was not significant, $F(1, 40) = 0.18$, $p < 0.675$, and the comparison of right hand tapping rate between groups was not significant, $F(1, 40) = 0.34$, $p < 0.565$.

The bright light exposure was expected to impact both groups to the extent that the right hand tapping rate would increase significantly. The depressed group was expected to demonstrate the greatest change due to a lower base rate. In fact the difference between group's right hand tapping rate between contexts was not significant, $F(1,40) = 1.53$, $p < 0.223$. Interestingly, the bright light context increased the left hand tapping rate in the depressed group to a greater extent than that seen in the non-depressed group (see Figure 7).

Insert Figure 7 Here

Dichotic Listening Data

It was hypothesized that the depressed group would have a smaller REA than the non-depressed group due to decreased left hemisphere activation. Although the data indicate that REA was indeed reduced in the depressed group (see Figure 8), it was not statistically significant, $F(1, 39) = 0.34$, $p < 0.563$.

The hypothesized under arousal of the left hemisphere in the depressed group was also expected to result in a reduced ability to shift focus to the right ear when compared to the non-depressed group. Again, a slight difference in the hypothesized direction is seen (see Figure 9). However, this group x condition interaction was not significant $F(2, 78) = 0.11$, $p < 0.892$.

The impact of bright light exposure was hypothesized to increase the REA in both groups; however, it was thought that the depressed group would not show as great a change as the non-depressed group. In fact, neither group experienced a significant change in REA (see Figure 10), and the groups are statistically equal in the group x context interaction, $F(1, 78) = 0.32$, $p < 0.577$.

The hypothesis that the bright light context would increase the depressed group's ability to shift focus to the right ear was not supported, $F(2, 78) = 0.54$, $p < 0.587$. Interestingly, in this case, too, the data were in the hypothesized direction (see Figure 11).

Insert Figure 8 Here

Insert Figure 9 Here

Insert Figure 10 Here

Insert Figure 11 Here

Post-Hoc Analyses

Post-hoc analyses to correct for possible differences in error rate between groups were done for this experiment. The error rate for the depressed and non-depressed groups was not significantly different, $F(1, 40) = 0.96$, $p < 0.336$. The pattern of errors between conditions and contexts was similar within groups, and differences between groups were within expected normal variation (see Figure 13).

Data were also manipulated to represent only those subjects who scored 13 or higher on the BDI and those who scored 5 or lower to push the limits of the inclusion criterion. However, analyses run following this "purification" of the data set yielded no striking changes in the results of either the dichotic listening or tapping rate data.

Insert Figure 12 Here

Insert Figure 13 Here

Discussion

This study was designed to clarify the connections among ambient light exposure, depression and age by using neuropsychological measures of laterality. To accomplish a more comprehensive evaluation of this relationship, groups of subjects with hypothetically different laterality patterns were chosen; old subjects were chosen by virtue of their anticipated decrease in right hemisphere functioning, and depressed subjects were chosen by virtue of their anticipated decrease in left hemisphere functioning. Pilot data suggested the possibility that bright light exposure selectively increases left hemisphere arousal, and previous studies have included both light and noise as independent variables for study; therefore, light was investigated exclusively as the independent variable in this study.

Behavioral measures of laterality were chosen which would not only provide data on the left versus right behavioral activity of the subjects, but which could also speak to the anterior versus posterior cerebral cortical zones. Finger tapping rate was chosen due to its primary locus of cortical control being anterior, and because distal extremities have strong contralateral cortical control. A dichotic listening task using consonant-vowel combinations as stimuli with no imposed delay was employed for a measure of lateral and more posterior cortical information. Although executing a proper response on the dichotic listening task required frontal cortical control, the method of double dissociation was to be incorporated with both tasks to separate anterior from posterior, and right from left.

The first experiment was designed to detect suspected differences between elderly and younger subjects which were based on earlier hypotheses of hemi-aging (i.e., that the right hemisphere of the older group was less functional). It was hypothesized that the older group would have a lower relative left hand tapping rate than the younger group due to right hemi-aging. What was found was that the older group's right and left hand tapping rate were closer to each other than the younger group's. The effector x group interaction was not statistically significant, however, with the older group having a reduced difference between hands in the standard context. These data are consistent with a theoretical decreased lateralization with aging such that the older women, as a result of increased experience with both hands, could adapt to a novel task with their left hand more effectively than the less experienced younger women. Another possible explanation of the results is that the older group, because of increased reactivity and longer habituation period, may have experienced a general cortical arousal which overshadowed differences between hands in such a novel set of conditions and context. The younger group, expected to have less reactivity and familiarity with the premises and context, evidenced the expected differences between dominant and non-dominant hands. Counterbalancing of contexts may have actually contributed to this effect in the older group. Half of each group was initially exposed to the bright light context, a purposefully arousing stimulus, while the other half was initially exposed to the "dim" or normal light context.

The elderly women, by nature of their hypothesized over-arousal and slow return to baseline, may have been at a high level of general cortical arousal during the whole of the experiment, and thus evidenced a possible ceiling effect. An analysis of the differences between those who received the bright light context first and those who received the dim context first was done post hoc to evaluate this possibility. A nested hierarchical design with group and initial context within group as class variables revealed a significant group by initial context main effect, $F(1, 50) = 4.53$, $p < 0.038$. In Figures 14 and 15 it is clear that while the younger group changed little between initial contexts (dim first versus bright first), the elderly group who received the bright context first experienced a higher finger tapping rate with both hands which changed little with subsequent changes in context, thus suggesting a ceiling effect. It should be emphasized that statistical tests on such small sample sizes, in this case 12 per cell, are questionable.

Insert Figure 14 Here

Insert Figure 15 Here

The first hypothesis for the dichotic listening task was that the older group would have a greater right ear advantage (REA) than the younger women because of hypothetical decreased competition from the right hemisphere cortex. In fact, both groups had statistically similar REA's in the normal or "dim" context. Again, the elderly women could have had an increased general cortical arousal which resulted in effective functioning in both hemispheres.

The next hypothesis was that the older group would have less attenuation of the REA than the young group (i.e., would not increase the LEA) while trying to focus on syllables entering the left ear. Theoretically, hemi-inattention from the elderly group's poorly functioning right hemisphere would make such a task more difficult. The data supported such a conclusion, as the younger group was actually able to effectively shift attention to the left ear (i.e., LEA), while the elderly group's data almost mirrored those in the non-focused condition. Again, the proposed ceiling effect for the elderly group cannot be ignored. However, the possibility of an experience (i.e., maturation) confound exists; the older group most likely has consistently used their right ears (verified by the lateral preference scale used as an inclusion criterion) to answer the phone, listen to radio, etc., and has developed a preference which may have been difficult to purposefully overcome.

The possibility that the older group was experiencing a ceiling effect of general cortical arousal compared to the younger group is further supported by the fact that during the bright light context the older women's tapping rate changed very little, while the younger group's left and right hands approached each other. In essence, in the bright light context, the younger women may have been reacting like the older women in all contexts. Elderly women are subject to more extensive experience during a longer period of development using their right ear and right hand than the younger women, and thus had a consistent response bias that was resistant to independent variable manipulation.

If the elderly group was indeed experiencing increased cortical arousal due solely to the experience of being in an experiment with insufficient time to habituate, then the third hypothesis regarding dichotic listening, that the older group would experience a greater REA in bright light than the younger group would not be supported because of an initially high base rate for the elderly group. As was stated above, the elderly group's response pattern between contexts was virtually identical, and the younger group's REA changed very little.

Finally, the hypothesis that the elderly group would increase their REA during the bright light context by purposely focusing right more effectively than the younger group due to increased reactivity received no statistical support. Neither group significantly increased the REA in the bright condition. The younger group, perhaps, had been driven to a high base rate by the bright light effects, and had little room to improve their REA purposefully through focusing attention on stimuli entering that ear, and thus more closely resembled the older group.

In summary, the first experiment revealed a stable response pattern in the older group across conditions and contexts which resembled that of the younger group in the bright light context. Of the initial hypotheses, only the second dichotic listening hypothesis was statistically supported; older women were expected to show less attenuation of the REA than the younger group during the focused-left condition.

The second experiment was designed to evaluate hypothesized differences between depressed and non-depressed subjects due to evidence that depressed people have decreased left hemisphere relative to right hemisphere functioning. It was hypothesized that the depressed group would have a lower relative right hand tapping rate than the non-depressed group due to left hemisphere dysfunction. In fact, the depressed group's right hand tapping rate was greater than that of the normal group, but the difference was not significant. Additionally, the main effect for groups was not significant. The difference between hands in these groups is interesting; the depressed group's left and right hand tapping rate was more discrepant than that of the non-depressed group. The effector x group interaction, of course, is moot in the context of insignificant main effects, but the pattern suggests increased lateralization in the depressed group.

Exposure to bright light was expected to impact both the depressed and non-depressed groups by increasing right hand tapping rate, and the depressed group was expected to experience the greatest change due to a lower base rate. However, the depressed group had a higher base rate than the non-depressed group. Regardless, the depressed group did indeed experience a greater right hand change while the left hand rate changed not at all. The non-depressed group had a minimal, but relatively equal increase in both hands. None of these changes resulted in statistically significant differences, therefore conclusions are strictly speculative. Yet, taken together the tests of the two tapping rate hypotheses indicate a change in right hemisphere functioning in the depressed group with a general increase in bilateral tapping rate in the non-depressed group. The theoretical selective impact of light on the left hemisphere, at least anterior cortex, is not supported unequivocally.

The dichotic listening hypothesis was designed to investigate the effect of depression and light on the posterior cortex. The first hypothesis was that the depressed group would have a decreased REA when compared to the non-depressed group as a result of theoretical left hemisphere dysfunction. Though not statistically significant, the REA in the depressed group was indeed lower than that in the non-depressed group. Additionally, the ability to focus attention to the right ear was expected to be reduced in the depressed group. This was also found to be the case, yet, again, with the difference being non-significant. A theoretically lower left hemisphere arousal in the depressed group was expected to change in the bright light context; light was thought to selectively increase left hemisphere functioning. Neither group changed significantly in this context, and no striking trends were seen.

Testing the limits of the dichotic listening paradigm, it has been suggested that asking the subject to focus on one ear or the other might increase sensitivity to changes in cortical activity (Kimura, 1967). It was hypothesized that the bright light context would increase the depressed group's ability to focus attention on the right ear. Although the data are in the proposed direction, the difference from the dim condition is not significant. Behavioral and cortical under-arousal in the depressed group should have resulted in group differences in the dim light context, and the depressed group had a greater difference between hands in the dim context. Such a state could be the result of hemispheric under arousal in comparison to the more consistent general hemispheric arousal of the non-depressed group. However, non-significant results are difficult to interpret unequivocally.

In summary, the dichotic listening data are in the proposed direction, however, effects were not outside chance occurrence, and the tapping rate data are opposite from the proposed direction while being within chance. The literature which was used to develop these hypotheses is composed of clinical data gathered from those with major affective disorder. It is possible that the effects of milder dysphoria on cortical activation are less than for more pronounced affective states (e.g., major depression), and result in reduced experimental changes. However, under arousal of cerebral cortex in the depressed group may have resulted in greater lateral differences in ear advantage and finger tapping.

The possibility that differences between groups were masked by errors in choosing dichotic CV's was examined post hoc. There was no significant difference between groups in error rate, and limiting data to those who made 75% correct responses did not improve the statistics.

Developing treatment recommendations from basic research alone is risky, and becomes fanciful when based on non-significant results. At most, one can say that ambient light has some measurable effect on elderly, young and depressed subjects. Whether these effects are beneficial must be determined using clinical populations and no-treatment controls.

If the elderly group in the first experiment was in fact experiencing a ceiling effect of behavioral arousal, then subsequent research projects should allow sufficient time for their subjects to habituate to the experimental environment. Differences in performance of subjects after different habituation periods could be investigated directly using this study's paradigm, while replacing light intensity with habituation period duration as the independent variable. This method may also tease out differences in depressed versus normal subjects.

Another possible refinement of the posterior cortical evaluation would be to use a tachistoscopic paradigm with a collection of verbal and affective stimuli following cortical arousal with ambient light. The use of subjects meeting criteria for major affective disorder is possible, and could be compared more readily to the current literature on laterality of depression; however, such a project may be outside the capability of purely academic environments. For anterior tasks (i.e., finger tapping rate) the dual-task paradigm has met with some success in clarifying differences between groups; however, simplifying the administration of the task, or limiting experiments to evaluating one system at a time is recommended.

Finally, using the above mentioned alternatives for investigation should be extended to male subjects, especially elderly males. This population is difficult to sample due to a lower number in the general population; however, they are more appropriate for studies of cerebral asymmetry due to their theoretically increased laterality.

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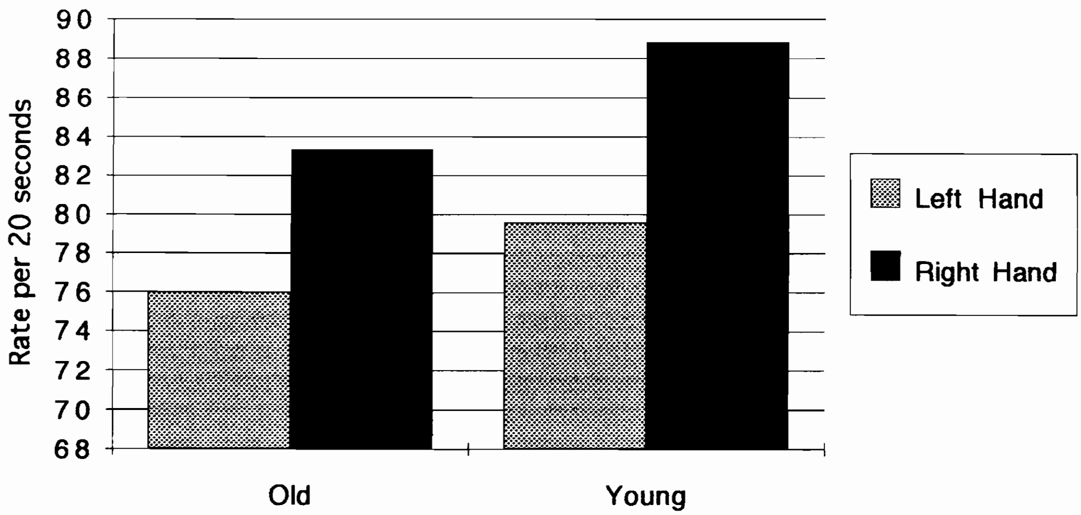


Figure 1: Old vs Young Finger Tapping Rate

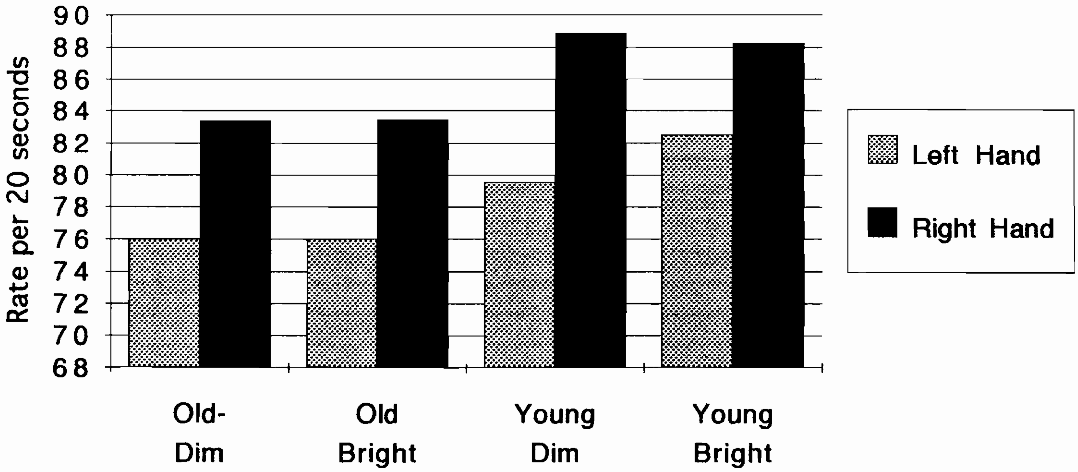


Figure 2: Old vs Young Subjects, Hand x Context

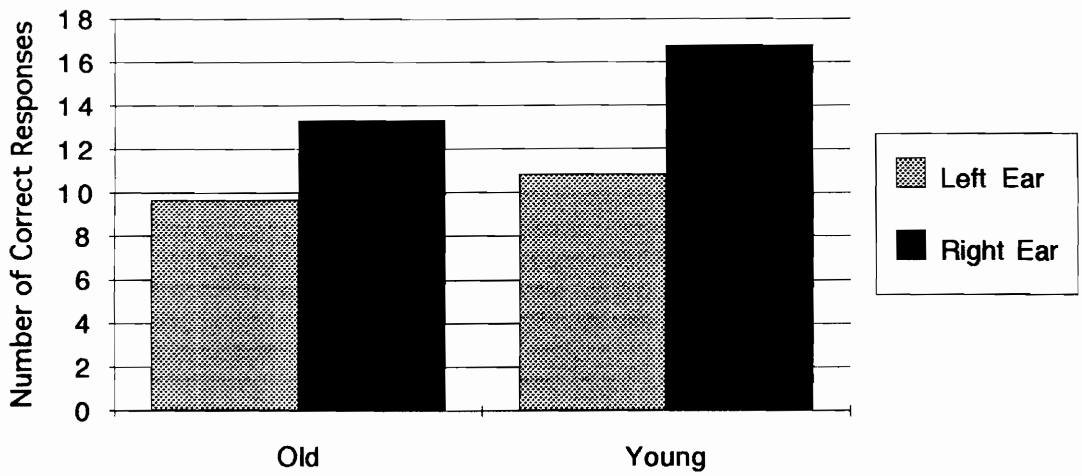


Figure 3: Old vs Young Subjects in Standard Dichotic Listening Paradigm

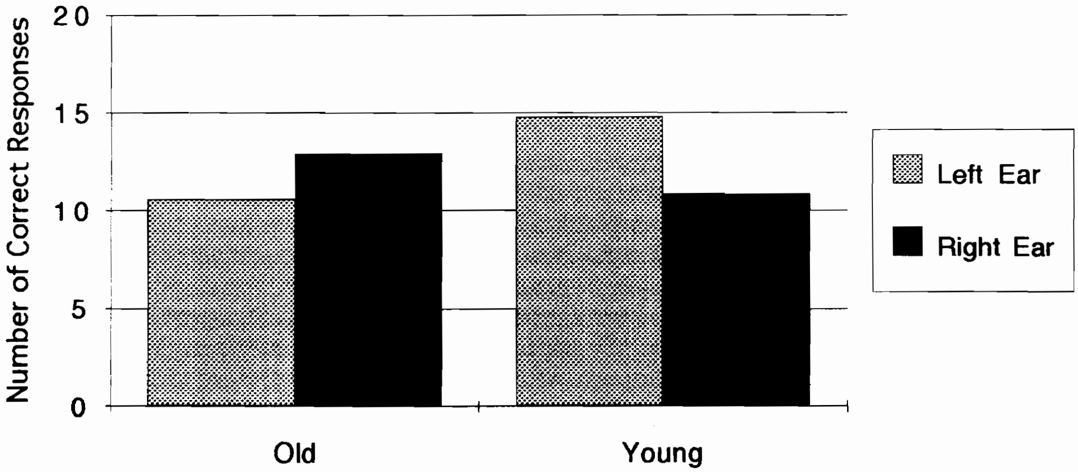


Figure 4: Old vs Young Subjects in Focused-Left Condition

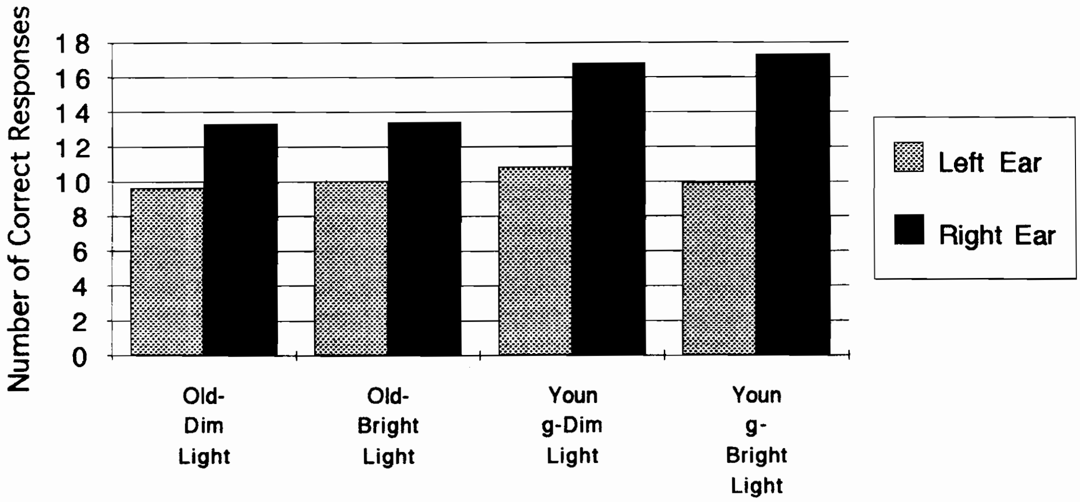


Figure 5: Old vs Young Subjects, Bright vs Dim Context in Standard Paradigm

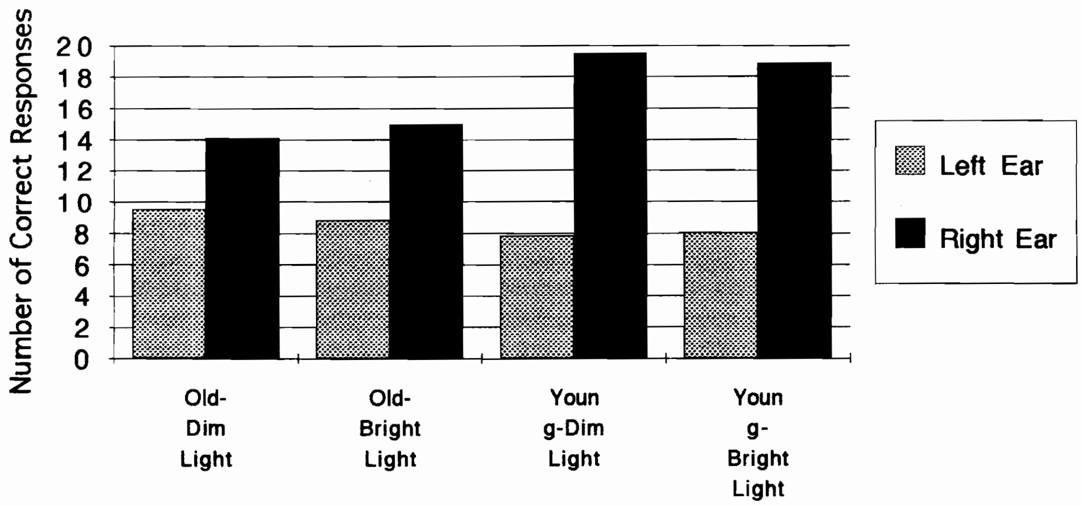


Figure 6: Old vs Young Subjects, Focused-Right Condition x Context

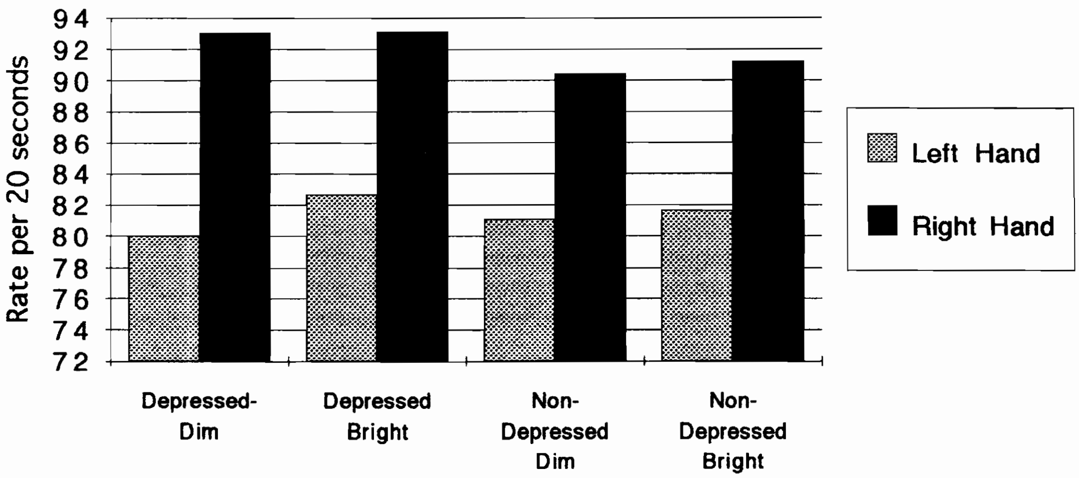


Figure 7: Depressed vs Non-Depressed Subjects, Hand x Context

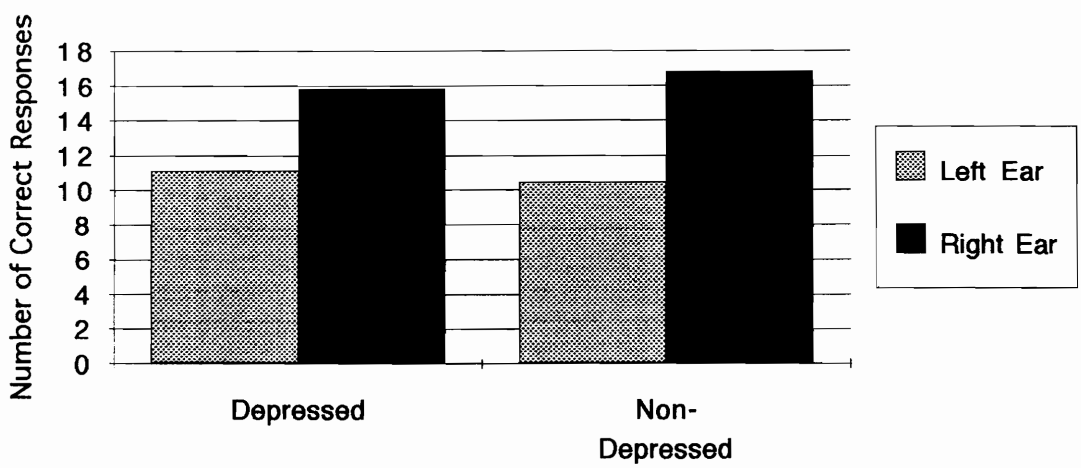


Figure 8: Depressed vs Non-Depressed Subjects in Standard Dichotic Listening Paradigm

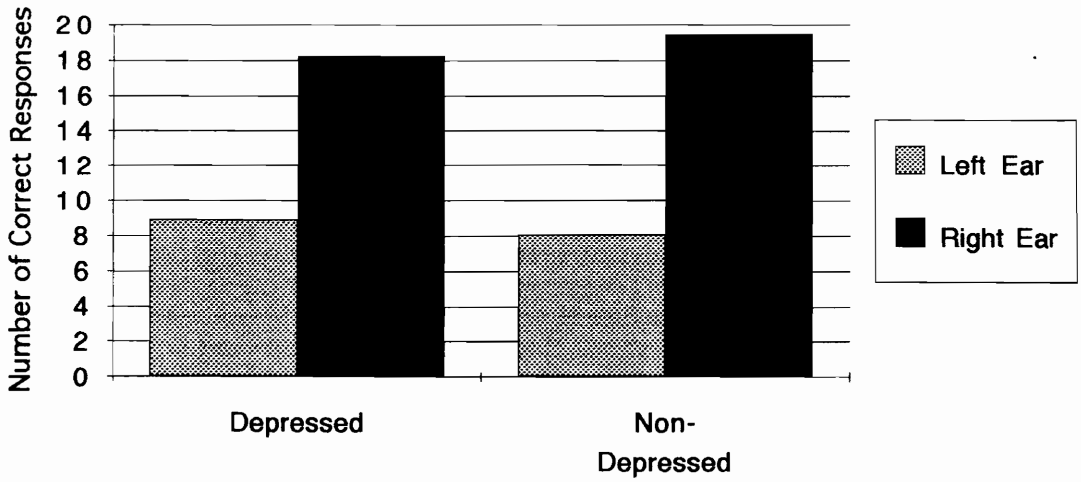


Figure 9: Depressed vs Non-Depressed Subjects in Focused-Right Condition

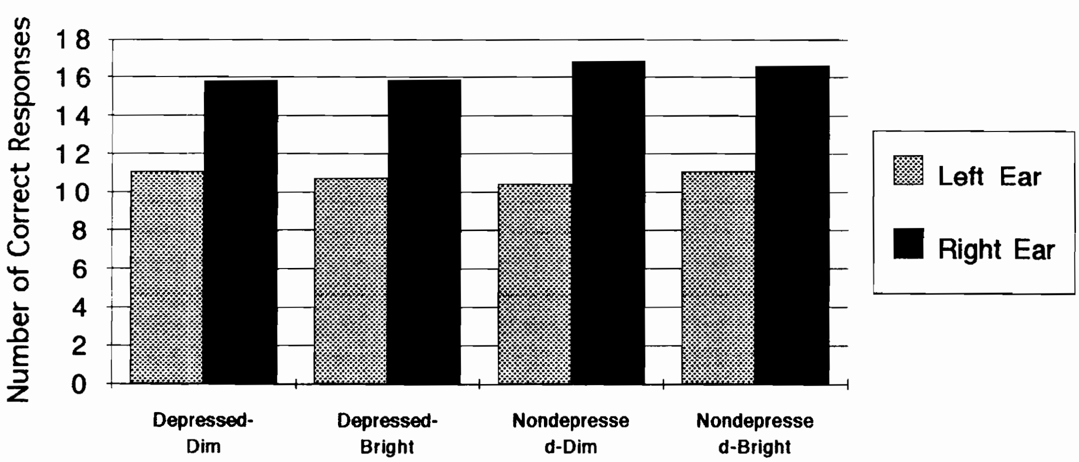


Figure 10: Depressed vs Non-Depressed Subjects, Bright vs Dim Context in Standard Paradigm

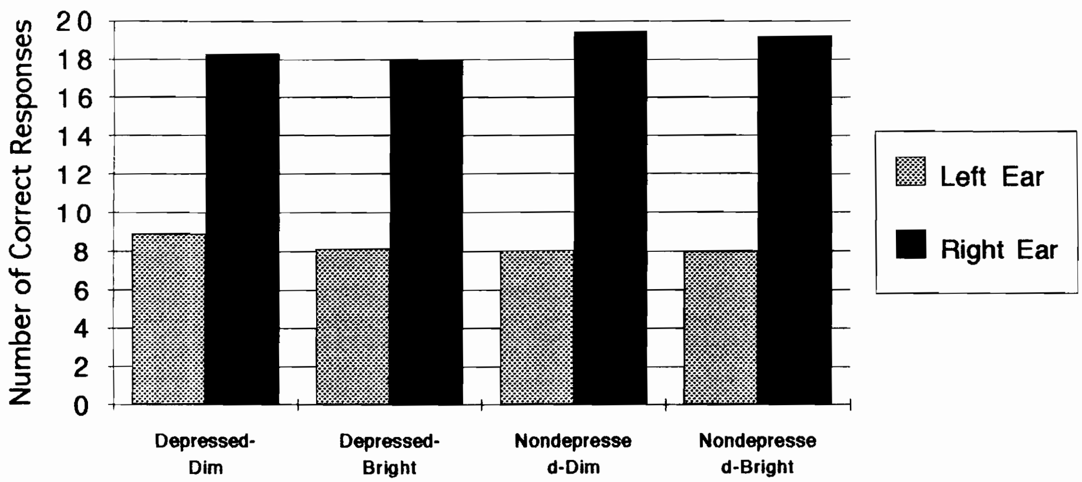


Figure 11: Depressed vs Non-Depressed Subjects, Focused-Right Condition x Context

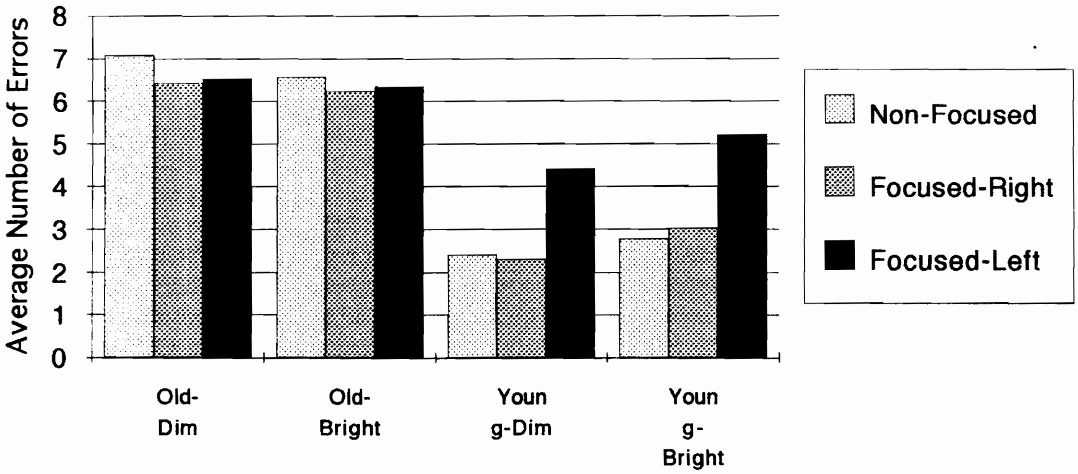


Figure 12: Age and Dichotic Listening Error Rate x Condition x Context

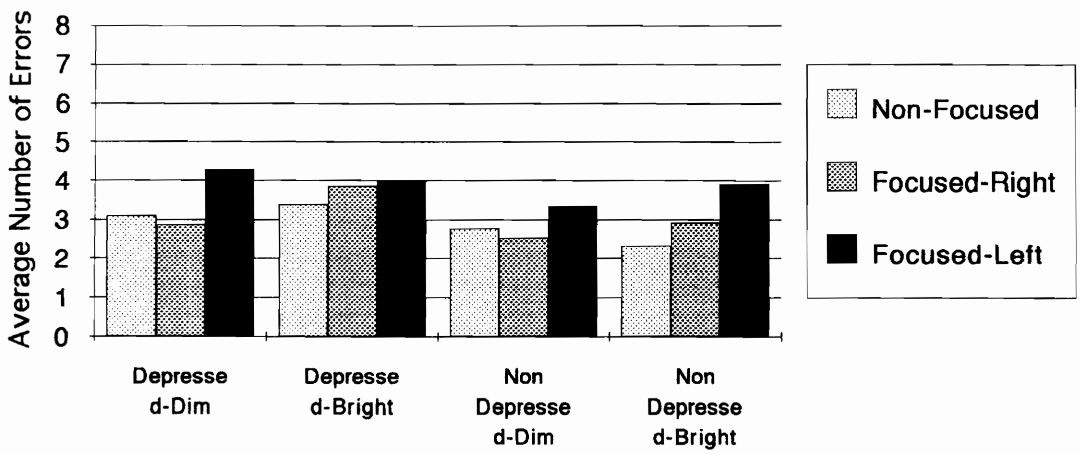


Figure 13: Affective State and Dichotic Listening Error Rate x Condition x Context

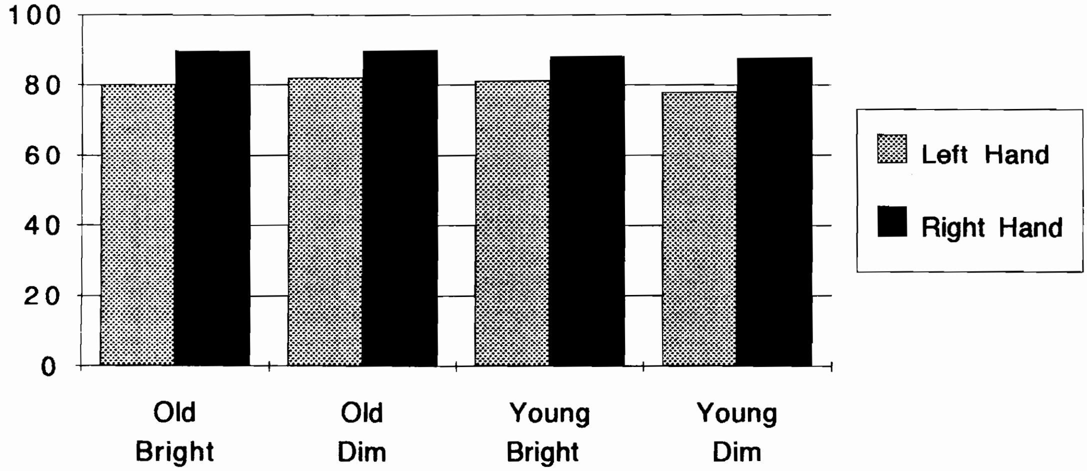


Figure 14: Tapping Rate for Those Receiving Bright Context First

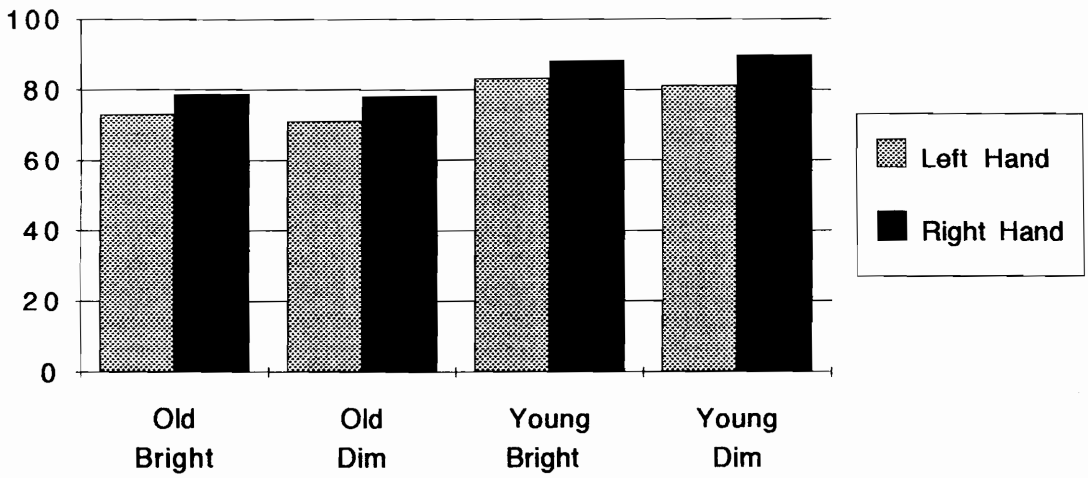


Figure 15: Tapping Rate for Those Receiving Dim Context First

Appendix A: Randomization/Counterbalancing table

Subject	Context	DL Cond	TP Cond	Context	DL Cond	TP Cond
1	A	123	12	B	132	12
2	B	123	21	A	132	12
3	A	132	12	B	123	21
4	B	132	21	A	123	21
5	A	123	12	B	132	12
6	B	123	21	A	132	12
7	A	132	12	B	123	21
8	B	132	21	A	123	21
9	A	123	12	B	132	12
10	B	123	21	A	132	12
11	A	132	12	B	123	21
12	B	132	21	A	123	21
13	A	123	12	B	132	12
14	B	123	21	A	132	12
15	A	132	12	B	123	21
16	B	132	21	A	123	21
17	A	123	12	B	132	12
18	B	123	21	A	132	12
19	A	132	12	B	123	21
20	B	132	21	A	123	21
21	A	123	12	B	132	12
22	B	123	21	A	132	12
23	A	132	12	B	123	21
24	B	132	21	A	123	21
25	A	123	12	B	132	12
26	B	123	21	A	132	12
27	A	132	12	B	123	21
28	B	132	21	A	123	21
29	A	123	12	B	132	12
30	B	123	21	A	132	12

Context: A=Bright B=Dim

DL Cond: 1=Non-Focused
2=Right-Focused
3=Left-Focused

TP Cond: 1=Right Hand
2=Left Hand

Appendix B: Coren, Porac & Duncan Handedness Questionnaire

Date:________Time:_________Subject #:__________

Circle the appropriate number after each item.

	Right	Left	Both
With which hand would you throw a ball to hit a target?	1	-1	0
With which hand do you draw?	1	-1	0
With which hand do you use an eraser on paper?	1	-1	0
With which hand do you remove the top card when dealing?	1	-1	0
With which foot do you kick a ball?	1	-1	0
If you wanted to pick up a pebble with your toes, which foot would you use?	1	-1	0
If you had to step up onto a chair, which foot would you place on the chair first?	1	-1	0
Which eye would you use to peep through a keyhole?	1	-1	0
If you had to look into a dark bottle to see how full it was, which eye would you use?	1	-1	0
Which eye would you use to sight down a rifle?	1	-1	0
If you wanted to listen to a conversation going on behind a closed door, which ear would you place against the door?	1	-1	0
If you wanted to listen to someone's heartbeat, which ear would you place against their chest?	1	-1	0
Into which ear would you place the earphone of a transistor radio?	1	-1	0

	# of Right	+	# of Left	= Total
Score	________	+	_______	= _______

Is mother left or right hand dominant?_______

Is father left or right hand dominant? _______

Appendix C: Beck Depression Inventory

On this questionnaire are groups of statements. Please read each group of statements carefully. Then pick out the one statement in each group which best describes the way you have been feeling the past week, including today! Circle the number beside the statement you picked. If several statements in the group seem to apply equally, circle each one. ***BE SURE TO READ ALL THE STATEMENTS IN EACH GROUP BEFORE MAKING YOUR CHOICE. ***

1. 0 I do not feel sad.
   1 I feel sad.
   2 I am sad all the time, and I can't snap out of it.
   3 I am so sad or unhappy that I can't stand it.

2. 0 I am not particularly discouraged about the future.
   1 I feel discouraged about the future.
   2 I feel I have nothing to look forward to.
   3 I feel that the future is hopeless and that things cannot improve.

3. 0 I do not feel like a failure.
   1 I feel I have failed more than the average person.
   2 As I look back on my life, all I can see is a lot of failures.
   3 I feel I am a complete failure as a person.

4. 0 I get as much satisfaction out of things as I used to.
   1 I don't enjoy things the way I used to.
   2 I don't get real satisfaction out of anything anymore.
   3 I am dissatisfied or bored with everything.

5. 0 I don't feel particularly guilty.
   1 I feel guilty a good part of the time.
   2 I feel guilty most of the time.
   3 I feel guilty all of the time.

6. 0 I don't feel I am being punished.
   1 I feel I may be punished.
   2 I expect to be punished.
   3 I feel I am being punished.

(over please)

7. 0 I don't feel disappointed in myself.
   1 I am disappointed in myself.
   2 I am disgusted with myself.
   3 I hate myself.

8. 0 I don't feel any worse than anybody else.
   1 I am critical of myself for my weaknesses or mistakes.
   2 I blame myself all the time for my faults.
   3 I blame myself for everything bad that happens.

9. 0 I don't have any thoughts of killing myself.
   1 I have thoughts of killing myself, but I would not carry them out.
   2 I would like to kill myself.
   3 I would kill myself if I had the chance.

10. 0 I don't cry any more than usual.
   1 I cry more now than I used to.
   2 I cry all the time now.
   3 I used to be able to cry, but now I can't cry even though I want to.

11. 0 I am no more irritated now than I ever am.
   1 I get annoyed or irritated more easily than I used to.
   2 I feel irritated all the time now.
   3 I don't get irritated at all by the things that used to irritate me.

12. 0 I have not lost interest in other people.
   1 I am less interested in other people than I used to be.
   2 I have lost most of my interest in other people.
   3 I have lost all of my interest in other people.

13. 0 I make decisions about as well as I ever could.
   1 I put off making decisions more than I used to.
   2 I have greater difficulty in making decisions than ever before.
   3 I can't make decisions at all anymore.

14. 0 I don't feel I look any worse than I used to.
   1 I am worried that I am looking old or unattractive.
   2 I feel that there are permanent changes in my appearance that make me look unattractive.
   3 I believe that I look ugly.

(over please)

15. 0 I can work about as well as before.
1 It takes an extra effort to get started at doing something.
2 I have to push myself very hard to do anything.
3 I can't do any work at all.

16. 0 I can sleep as well as usual.
1 I don't sleep as well as I used to.
2 I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
3 I wake up several hours earlier than I used to and cannot get back to sleep.

17. 0 I don't get more tired than usual.
1 I get tired more easily than I used to.
2 I get tired from doing almost anything.
3 I am too tired to do anything.

18. 0 My appetite is no worse than usual.
1 My appetite is not as good as it used to be.
2 My appetite is much worse now.
3 I have no appetite at all anymore.

19. 0 I haven't lost much weight, if any, lately.
1 I have lost more than 5 pounds.
2 I have lost more than 10 pounds.
3 I have lost more than 15 pounds.
*** > I am purposefully trying to lose weight by eating less YES/NO

20. 0 I am no more worried about my health than usual.
1 I am worried about my physical problems such as aches and pains; or upset stomach; or constipation.
2 I am very worried about physical problems and it's hard to think of much else.
3 I am so worried about my physical problems that I cannot think about anything else.

21. 0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I am much less interested in sex now.
3 I have lost interest in sex completely.

Appendix D: Informed consent form

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

Virginia Polytechnic Institute and State University,
Blacksburg, VA 24061

You are being asked to volunteer as a participant in a research study. This form is designed to provide you with information about the study and to answer any of your questions.

Title of Research Study: Hemispheric Reactivity to Bright Light Exposure

Project Director:	John Dale Alden, III, M.S.	phone: 951-4939
Project Supervisor:	Dr. David W. Harrison	phone: 961-4422

PURPOSE OF THE RESEARCH: To evaluate your ability to make decisions about vowel consonant combinations, and to perform a combination tapping and reading task.

EXPERIMENTAL PROCEDURE: You will be asked a number of questions and to fill out a questionnaire. Some of the questions may be personal in nature. If they are too personal, you do not have to answer them. The particular tasks will involve listening to recorded sounds and reporting what you hear, and will involve a finger-tapping exercise and a reading exercise.

RISKS: If you wish to discuss these or any other discomforts you may experience, you may call the project director. However, since most of the tests are evaluative, there are no serious risks involved. You may cease participation in the experiment at any time. This session should last from one hour to one hour and a half.

POTENTIAL BENEFITS: By participating in this study, you may gain new knowledge of experimental design or protocol which might prove helpful in the future. If you wish to know the results of your tests, you may receive this information at the end of the study by contacting the project director.

ALTERNATIVE TREATMENT OR PROCEDURE: No alternative procedures will be used.

If the data from this experiment cannot be treated in such a way as to maintain the anonymity of the subjects, then it will not be used for any purpose other than those we have described without their consent. Subjects in this experiment will not be identified by name or other identifiers and personal data will remain confidential. If you appear suicidal or at risk of harm to yourself or others, then consultation and information on appropriate referrals will be given you directly by the project director and/or supervisor. This project has been approved by the Human Subjects Research Committee and the Institutional Review Board (**Approval # 1037-90**).

Any questions you may have about this experiment should be directed to : John Dale Alden, III, M.S. (951-4939) or David W. Harrison, Ph.D. (961-4422). Questions concerning Human Subjects Research Committee approval should be addressed to Dr. Helen Crawford (Dept. of Psychology) or Dr. Ernest Stout (Dept. of Biology).

I hereby agree to voluntarily participate in the research project described above and under the conditions described above. I have read this consent form and understand the project described. All of my questions have been answered to my satisfaction.

Signature of Participant: ____________________________Date:_________

Printed Name: ___________________________________

ID no (For Intro Psych Students):___________________________

Appendix E: Data collection sheet

Subject # _________ Date: _________ Time: _________

Age:_________

Examiner: ___________________

BDI Time 1:_________

BDI Time 2: _________

Handedness: _________

Reading Rate: _________

===

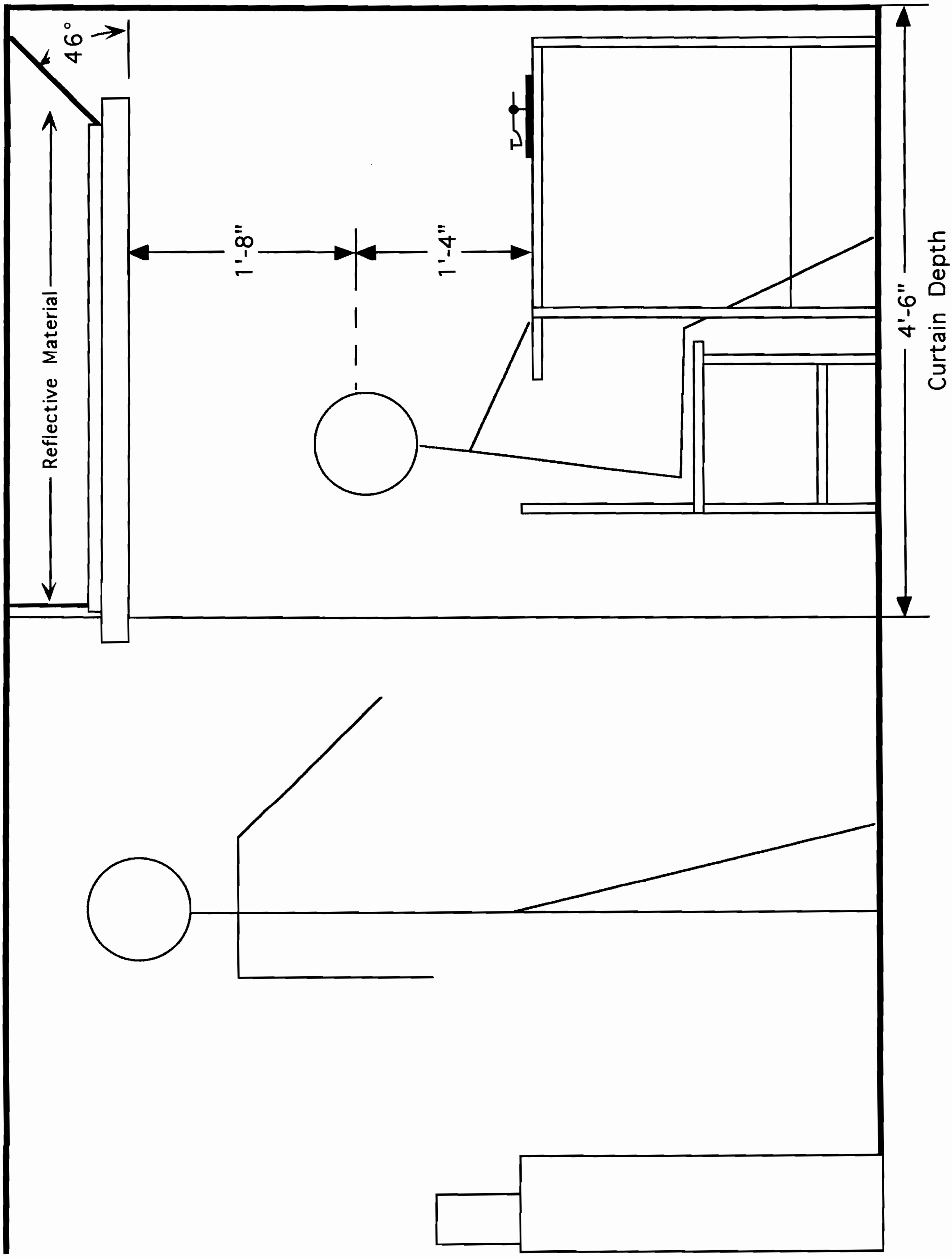
Initial Questions:

1. Have you had any alcohol, perscription or over the counter drugs in the past 24 hours? _________

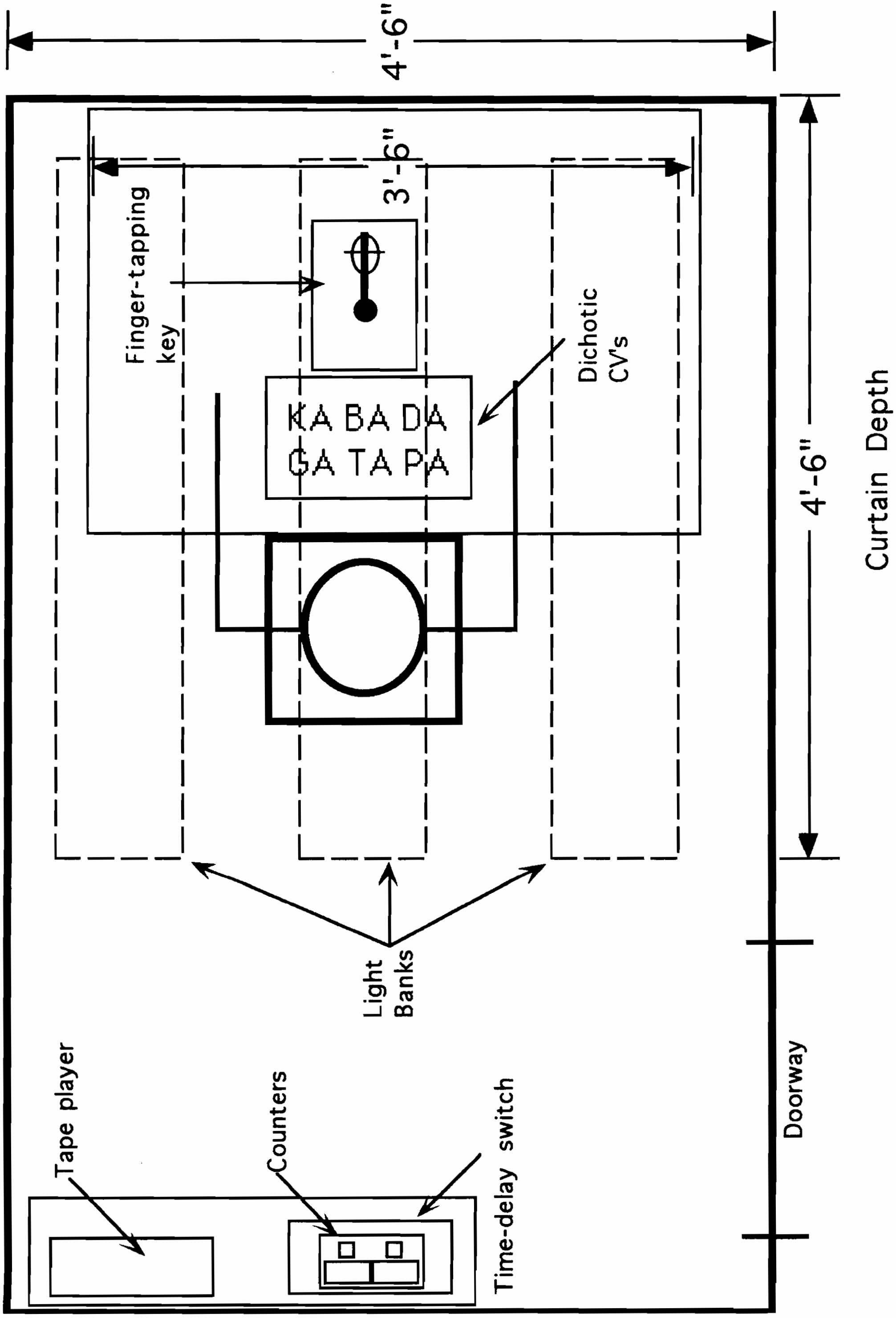
If yes, what? ____

2. Are you right handed or left handed? _________
3. Do you have any trouble with your eyes? _________
4. Do you have any trouble with your ears? _________
5. Do you have any trouble with either hand? _________
6. Do you have a history of any neurological problems? _________

Appendix F: Experimental environment



Appendix G: Experimental environment



Experimental Chamber: Top View

VITA
JOHN DALE ALDEN, III

Born: January 6, 1962, Memphis, TN

EDUCATION

B.A. Freed-Hardeman University, 1985 (with honors)
Major field of study: Psychology/Philosophy

M.S. Abilene Christian University, 1987
Major field of study: Clinical Psychology
Major advisor: Dr. Clyde Austin

Title of Thesis: The Geriatric Depression Scale Long Form and Short Form: Convergent validity and a comparison of nursing home residents and elderly people living independently.

RECENT PROFESSIONAL EMPLOYMENT

Present Clinical Fellow of Neuropsychology and Geropsychiatry, Division of Medical Psychiatry, Vanderbilt University Medical Center

1991-1992 Clinical Psychology Intern, Division of Medical Psychiatry/Geropsychiatry, Vanderbilt University Medical Center

1991-1992 Clinical Psychology Intern-Behavioral Medicine, Department of Anesthesiology Pain Control Center, Vanderbilt University Medical Center

1990-1991 Faculty Instructor, Department of Psychology, Hollins College, Roanoke, Virginia

REFEREED PUBLICATIONS

Alden, J. D., Crews, W. D. & Harrison, D.W. (1991). Cerebral asymmetry in dementia: Effect of context on hemi-attention. Perceptual and Motor Skills, 72, 802.

Alden, J. D., Austin, C. N. & Sturgeon, R. S. (1989). A correlation between the Geriatric Depression Scale Long and Short Forms. Journal of Gerontology, 44(4), 124-125.

Harrison, D. W., Lanter, J. J., Alden, J. D. & Zicafoose, B. F. (1990). Sensory modification of nonpropositional speech: Excessive emotional vocalization disorder with dementia. Neuropsychology, 4, 215-221.

John Dale Alden, III 2/5/93
Date