THE NEUROBEHAVIORAL CORRELATES OF AFFECT PERCEPTION AS A FUNCTION OF VERBAL FLUENCY CLASSIFICATION

by

Katharine A. Snyder

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APPROVED:

David W. Harrison, Chairperson

Helen J. Crawford

Albert M. Prestrude

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(ABSTRACT)

The Dichotic Emotional Words Tape developed by Bryden and MacCrae (1989) was used to assess cerebral asymmetry for propositional and nonpropositional speech as a function of verbal fluency. Forty-five right-handed subjects with normal auditory acuity for pure tones were assigned to a verbal fluency classification based on scores on the FAS test (Borkowski, Benton, & Spreen, 1967). After being assigned to a fluency category, subjects were instructed to listen for a word (bower, dower, power, or tower) or affective tone (happy, sad, angry, or neutral). The most important findings of this study were the main effects of fluency (higher, middle, and lower), stimulus type (word and affect), and focus or intention (focus left and focus right). Subjects higher in fluency exhibited significantly greater REA and LEA scores than subjects lower in fluency. For stimuli presented to the right ear, scores for words were significantly greater than scores for affect. However, for stimuli presented to the left ear, scores for affect were significantly greater than scores for words. Focus left instructions led to increases in LEA scores, while focus right instructions led to increases in REA scores. Directions for future research are discussed.

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INTRODUCTION

On the issue of cerebral asymmetry, a great deal of research has indicated that language processes are primarily a function of the left hemisphere, while affective and spatial processes are predominantly a function of the right system. However, ambiguous empirical findings throughout the literature indicate that these broad functional generalizations cannot be made. When the elemental processes of language and affect are assessed, it becomes apparent that both cerebral systems are necessary for the perception and expression of speech and emotion. The purpose of this introduction is to survey literature on cerebral asymmetry for the perception of language and emotion in an attempt to determine the functional roles of both systems.

Language

One of the most useful clinical theories of cerebral asymmetry for language is the Wernicke-Geschwind model (Geschwind, Quadfasel, & Segarra, 1968). Regardless of whether language stimuli come in via auditory or visual channels, this model proposes that Wernicke's area (left posterior superior temporal lobe) mediates comprehension and Broca's area (adjacent to the left precentral gyrus) mediates articulation.

Although aphasia studies provide a great deal of support for this model, it does not adequately explain why more extensive lesions including subcortical structures (e.g. left thalamus or left caudate nucleus) lead to more extensive dysfunction. In fact, research has suggested that different pathways exist for sounds, phonological aspects, and semantic content.

This section will evaluate the Wernicke-Geschwind model (Geschwind, et al., 1968) in terms of its implied prediction of left cerebral superiority for language processes in general. A survey of research involving lesions, reading disabilities, and dichotic listening seems to indicate that both the right and left systems play a role in language processes.

<u>Lesion Studies</u>. Earliest empirical support for the Wernicke-Geschwind model in terms of the left functional asymmetry for language came from aphasic patients. The following types of aphasias are

characterized by reductions in verbal fluency or conversational speech output: Broca's aphasia (left inferior frontal), global aphasia (left frontal temporal parietal), transcortical motor aphasia (left medial frontal), and mixed aphasia (left medial frontal parietal).

Many aphasic studies suggest that the left system plays a dominant role in language production, grammaticism, and articulation. Research has demonstrated that damage to left frontal regions leads to impairments in conversational speech and word generation (Benton, 1968; Geschwind, 1970, 1972; Kimura & Watson, 1989; Milner, 1967). Likewise, research has shown that damage to left posterior temporal regions leads to impairments in comprehension rather than conversational speech (Bolter, Long, & Wagner, 1983; Miceli, Caltagirone, Gainotti, Masullo, & Silveri, 1981; Pendleton, Heaton, Lehman, & Hulihan, 1982).

On the other hand, studies of aprosodic patients indicate that certain aspects of language, such as musical intonation or prosody and emotional gesturing, are functions of the right system. Aprosodia is characterized by difficulties in comprehending and expressing aspects of language which involve prosody or intonation (Tucker, 1981). Organization of prosody in the right system seems to parallel organization of articulation and comprehension in the left system (Ross, 1981). Lesions of the anterior right system, analogous to Broca's area, result in monotone speech and blank facial expression regardless of affective state (Ross, 1981; Gorelick & Ross, 1987). Lesions of the posterior right system, homologous to Wernicke's area, results in reduced comprehension of emotional prosody and inappropriate intonation (Ross, 1981; Gorelick & Ross, 1987). Similarly, other studies have shown that aprosodic patients have difficulty emitting affective facial expressions (Buck & Duffy, 1980) and show less skin conductivity changes (Morrow, Urtunski, Kim, & Boller, 1981) in the presence of emotionally charged stimuli.

In conclusion, research involving brain damaged patients seems to suggest that left cerebral systems are more involved in the production, comprehension, and articulation aspects of language, while the right cerebral systems are more involved in the comprehension and expression of prosodic aspects of language.

Reading Disability Studies. Research in the area of dyslexia or reading disabilities has also implicated a more holistic model of language and the current trend is identification of pathways as opposed to overall asymmetry (Baynes, 1990; Thal, et al., 1991). Although progress has been made, research in this area has been far from conclusive due to lack of definition of the nature of the reading disabilities and inappropriate or inadequate controls.

One line of research suggests that dyslexics have anomalous asymmetry for language, as indicated by an overreliance on the right cerebral system (Annet & Kilshaw, 1984; Witelson, 1977). Schweiger, Zaidel, Field, and Dobkin (1989), for instance, showed that the performance of dyslexics with Broca's aphasia did not significantly differ from controls on a tachistoscopic word recognition task when stimuli were given to either the left or both hemifields. Beaumont, Thompson, and Rugg (1981) showed that dyslexic subjects demonstrated less of a right-ear advantage for word identification than controls. Thomson (1976) and Zurif and Carson (1970) demonstrated that dyslexic readers in contrast to normal readers showed a left ear advantage for both digits and words.

In support of this, Hagopian, Harrison, and Alden (1992) have found differences in performance on dichotic listening tasks as a function of reading-disability. Under nonfocused conditions, reading-disabled children exhibited a weaker REA than non reading-disabled children. When given focus left instructions, reading-disabled children unlike the non reading-disabled children showed no REA. These results suggest that reading-disabled children, possibly like lower fluency subjects, exhibit less functional asymmetry for language and are more adversely effected by attentional instructions.

However, some research has not supported this theory. Kershner and Morton (1990) and Kershner and Stringer (1991), for example, found the dyslexic readers exhibited a right ear advantage for word identification which was not significantly different from normal readers. Morton and Siegel (1991) showed that dyslexic readers exhibited a right ear advantage for digits and a left ear advantage for consonants or vowels. Gillas (1978) found that dyslexic subjects responded faster when feedback was given to the right ear than when feedback was given to both ears.

In fact, some researchers have suggested that studies supporting the right-shift hypothesis (Annet & Kilshaw, 1984) are simply measuring differences between normal and impaired readers in attention. Smith and Griffiths (1987), for instance, showed that dyslexic subjects, unlike normal readers, were unable to identify tones entering the left ear when instructed to focus on the right ear. Kinsbourne and McMurry (1975) showed that dyslexic subjects have more difficulty with time sharing or dual tasks (e.g. speaking and tapping at the same time) than do non-dyslexic subjects.

Although research on the right-shift hypothesis is far from conclusive, it does indicate that the right cerebral system has a functional role in language processes in addition to the left cerebral system (Witelson, 1977). Interestingly, Huntzinger and Harrison (1992) demonstrated that nonfluent dyslexic readers exhibited deficits characteristic of anterior cerebral dysfunction, whereas fluent dyslexic readers exhibited signs of posterior cerebral dysfunction. Larson (1984) showed longitudinally that the right ear advantage for word identification decreases with age for normal readers. Could differences in tasks aimed at anterior or posterior cerebral function be confounding the conclusions of studies assessing the right-shift hypothesis? Would these anterior and posterior functional differences be found in adult subjects of higher or lower fluency with or without dyslexia? Does the right system play more of a role in language with age? Do different patterns of developmental changes in asymmetry differentiate the dyslexic from the normal reader in relation to language? Answers to these questions await future research and tightly controlled sequential designs.

Intelligence Studies What is meant by high and low verbal abilities is inferred by differences in performance on several tests. This study operationally defined verbal ability by the FAS test and subjects classified as having better verbal abilities (higher FAS scores) were expected to have higher scores on a dichotic listening test. We proposed that subjects higher in verbal abilities are so because of greater involvement of left cerebral system in the perception of propositional and nonpropositional speech (Annet & Kilshaw, 1984). Other researchers, however, have proposed different operational definitions of verbal ability and have proposed different neurological reasons for variability in verbal skills.

Hunt, Lunneborg, and Lewis (1975), for example, operationally defined verbal abilities using the Washington Pre-College Test. Subjects were categorized as having high or low verbal abilities based on the english usage, spelling, reading comprehension, and vocabulary scales of this test. Subjects were presented with one to five characters for five seconds and asked to indicate whether the target character was present. Subjects classified as having higher verbal abilities had faster reaction times on this task. Using the same operational measure of verbal abilities, Wickens (1972) found that changing the category of words (animals to vegetables) in lists which subjects were to memorize reduced proactive inhibition only for subjects higher in verbal abilities. Thus, subjects higher in verbal abilities could be so because of faster processing of verbal stimuli (Hunt, et al., 1975) and less susceptibility to interference (Wickens, 1972).

Interestingly, Hunt, Lunneborg, and Lewis (1975) have pointed out that many dichotic listening studies using higher verbal ability subjects have found no right ear advantages for language perception, while studies using subjects having lower verbal abilities have shown the expected right ear advantages for language perception. Thus, subjects higher in verbal abilities might utilize both cerebral systems more and show less patterns of lateralization, while subjects lower in verbal abilities might utilize both cerebral systems less and show greater patterns of lateralization in the perception of language.

Dichotic Listening Studies. A great deal of research has indicated that subjects not manifesting any language or reading problems show a right ear asymmetry (REA) for word identification (Bryden, 1978; Springer, 1987). However, subjects exhibiting language or reading problems tend to show significantly less of this REA (Hagopian, Harrison, & Alden, 1992; Hiscock & Kinsbourne, 1980; Hugdahl & Anderson, 1987; Obrzut, Hynd, Obrzut, & Leitgeb, 1980; Obrzut, Obrzut, Hynd, & Pirozzolo, 1981).

Many studies support the notion of left asymmetry for language. Borowery and Goebel (1976), for instance, found a right ear advantage for language production across age, sex, race, and socioeconomic status. Coffey, Bryden, Schroering, and Wilson (1989) showed that indices of regional cerebral blood flow and dichotic listening both suggested left asymmetry for language. Pinsky and McAdam (1980) and Gruber and Powell (1974) performed four experiments demonstrating that subjects who either stuttered or did not stutter both exhibited a right ear advantage.

Other studies propose that both the left and right systems play a role in language. Kreiman and Van-Laucker (1988), for example, have found a left ear advantage for voice recognition (e.g. soprano, alto, tenor, bass) and a right ear advantage for word recognition. Deutsch (1985) found that musically trained individuals unlike those without musical training, exhibited a left ear advantage for higher tones of voice and a right ear advantage for lower tones of voice. Borowery and Goebel (1976) found that subjects from middle socioeconomic levels exhibited a greater REA for language than did subjects from a lower socioeconomic level. Andrews, Quinn, and Sorby (1972) and Brady and Berson (1975) have provided research to support a theory that individuals who stutter have uncoordinated bilateral speech processes and significantly less REA for language. Several researchers have also demonstrated that the use of higher intensity visual, auditory, or cutaneous stimuli reduces the REA for language (Cheathan, 1990; Iaccino & Houran, 1989; Maaser & Farley, 1989).

Thus, both left and right systems appear to have some functional role in language. Although these studies on verbal communication provide support for a holistic model, the most convincing research on the role of the right system in communication comes out of the research of Ley and Bryden (1979) which indicates that nonpropositional speech is primarily a function of the left system and propositional speech is primarily a function of the right system. This phenomenon has been extensively replicated (Benton & Van Allen, 1968; Borod, Koff, Perlman-Lorch, & Nicholas, 1986; Borod, Lorch, Koff, & Nicholas, 1987; Diamond, Farrington, & Johnson, 1976; Gainotti, 1972; Kolb & Taylor, 1981; Levy, Heller, Banich, & Burton, 1983; McFarland & Kennison, 1989; Milner, 1967, 1975; Morgan, McDonald, & McDonald, 1971; Rinn, 1984; Sackheim & Grega, 1987;

Sackheim, Gur, & Saucy, 1978; Sergent, 1985; Shipley, Dingwell, & Berlin, 1988; Wale & Carr 1990) and will be the focus of the next section on emotional communication.

Emotion

Spoken and written words are only a few of the ways that we communicate, we also convey information to others through tone of voice, posture, gestures, and facial expressions. In fact, studies by Ekman (Ekman & Friesen, 1971; Ekman, 1980) have shown that isolated New Guinia tribes can identify emotions based on facial expressions as accurately as Westerners can. The purpose of this section will be to show that both cerebral systems play a role in mediating affect recognition and expression.

Studies With Non-Clinical Samples. Research by Bryden, Ley, and colleagues has indicated that the right cerebral system plays a more important functional role in visual affect recognition then the left cerebral system. In addition to finding a right hemifield advantage for word recognition (Bryden & Ley, 1983), Ley and Bryden (1979) demonstrated a left hemifield advantage for facial affect recognition in tachistoscopic tests. Specifically, no differences in recognition accuracy occurred between the left and right hemifields for neutral expressions, while a left hemifield advantage occurred for emotional expressions. Similarly, other researchers have found that emotional and stressful questions led to increased left lateral eye movements (Schwartz, Davidson, & Maer, 1975; Tucker, Roth, Arnespon, & Buckingham, 1977).

This right system recognition advantage also occurs when stimuli are presented dichotically. For instance, Bryden, Ley, and Sugarman (1982) showed that accuracy of identification of modes is greater when melodies are presented to the left ear. Similarly, when subjects were asked to report the verbal and affective content of a spoken passage (Ley & Bryden, 1982), verbal content was more accurately reported when it was presented to the right ear and affective content was more accurately reported when it was presented to the left ear. Similarly, when stimuli were administered monaurally, subjects showed a greater left ear advantage for identifying emotional tones of voice and a greater right ear advantage for identifying verbal content (Safer & Leventhal, 1977).

Right functional cerebral asymmetry has also been demonstrated for emotional expression. Both Sackheim, et al. (1978) and Moscovitch and Olds (1982) showed that unevoked or natural affective expression is more intense on the left side of the face.

While this research indicates a right system advantage for all types of affect expression and recognition (Gainotti, 1983; Ley & Strauss, 1986), other studies have suggested functional asymmetry of the right system for negative and left system for positive affective recognition and expression (Silberman & Weingartner, 1986; Tucker, 1981). In addition to showing that subjects exhibit a left ear advantage (LEA) when identifying whether stimuli are affective or not (Ley & Strauss, 1986), research has documented a LEA for identifying negative and a REA for identifying positive or neutral affective tone (Bryden & MacCrae, 1989; Ley & Bryden, 1979; Suberi & McKeever, 1977).

Along the same lines, Harrison and Gorelczenko (1990) found that identification of affective valence was fastest when stimuli were presented to the left visual field (right hemisphere). Differences due to sex were also found in this study, such that women exhibited fewer lateralization patterns and were slower at identifying the affective valence of stimuli presented to the left visual field (right hemisphere) than men.

Other researchers have proposed that the left system plays an inhibitory role in affect expression and recognition (Bakan, 1969; Galin, 1974). For instance, Tucker, Antes, Stenslie, and Barnhard (1978) showed that subjects reporting high test anxiety exhibited a decrement in verbal performance when stimuli were presented to the right hemifield. Similarly, Kinsbourne (1970) reported a significantly greater right ear advantage for identifying verbal content in subjects reporting high test anxiety as compared to those not reporting test anxiety.

<u>Studies with Clinical Samples</u>. Babinski (see, Tucker, 1981) was one of the first to report that right system damage led to euphoric or indifferent reactions, while left system damage led to despair. This supports a theory of right asymmetry for affect expression and recognition, in that left system damage leaves the

right system intact to respond emotionally to the injury whereas right system damage impairs the ability to respond emotionally to the injury (Goldstein, 1948). If the two systems have differential involvement in affect expression and recognition, than subjects exhibiting different levels of affect expression could also be exhibiting different levels of asymmetry (Tucker, 1981). In support of this, research has shown that individuals who exhibit higher levels of affective responses to emotional stimuli tend to exhibit more left eye movements (Gur & Gur, 1975; Shapiro, 1965).

Many studies have shown that right system injury leads to greater impairments in affect recognition than left system injury. For instance, patients with left system lesions were much more accurate at identifying affective tone of voice than patients with right system lesions (Heilman, Scholes, & Watson, 1975; Tucker, Watson, & Heilman, 1977). In fact, Heilman, et al. (1983) documented a case of a severely left system impaired individual with word deafness and lack of speech comprehension, but who nevertheless could identify the affect expressed in differing tones of voice. DeKosky, Heilman, Bowers, and Valenstein (1980) demonstrated that right system damage impairs facial affect recognition much more than left system injury.

Similarly, many studies have shown that right system injury leads to greater impairments in affect expression than left system injury. Buck and Duffy (1980) showed that patients with right system damage exhibited fewer affect expressions in response to emotionally graphic slides than patients with left system damage. Ross and Mesulam (1979) demonstrated that patients with right system damage had difficulties expressing affect through voice inflections. Morrow, et al. (1981) showed that patients with right system damage exhibited fewer skin conductivity changes during the presentation of emotionally graphic slides than did patients with left system damage.

Research with clinical samples has also indicated a right system advantage for negative and left system advantage for positive affective recognition and expression (Tucker, 1981). Davidson, Ekman, Saron, Senulis, and Freisen (1990), for instance, found that disgust is associated with frontal regions of the right hemisphere and happiness is associated with temporal regions of the left hemisphere.

In general, patients suffering from affective disorders show impairments in the right frontotemporal regions (Flor-Henry, 1974, 1976). For instance, Bruder and Yozawitz (1979) found that the tendency for patients to report that symptoms were less severe correlated with decrements in the left ear advantage for identifying emotional content. A great deal of research has indicated that depressed patients show intensive impairments in the right system (Cohen, Penick, & Tarter, 1974; Goldstein, Fillskov, Weaver, & Ives, 1977; Kronfol, Hamsher, Digre, & Waziri, 1978; Perris, 1974). Although the particular combination of depressive symptoms exhibited seems to be correlated with levels of activation of different regions of right frontal area (Perris & Monokhov, 1979; Perris, Monokhov, von Knorring, Botskarev, & Nikiforov, 1989), it is generally well supported that higher levels of beta activity in the right frontal system correlated with higher levels of sad affect in depressed patients (Perris & Monokhov, 1979).

While research with depressive patients has helped to delineate the role of the right cerebral system, research with schizophrenic patients has helped to define the role of the left system in affect expression and recognition. Disorders having symptoms characteristic of schizophrenia have been associated with impairments in the left temporal lobe (Bingley, 1958; Davidson & Bagley, 1969; Taylor, 1975). For instance, patients with epileptic foci in the left temporal lobe exhibited schizophrenic symptoms during seizures or periods of high reactivity of this region (Flor-Henry, 1969, 1974, 1976; Gur, 1977). Many researchers have demonstrated that schizophrenics exhibit high reactivity in the left system (Abrams & Taylor, 1975; Gur, 1977; Roemer, Shagass, Straumanis, & Amadeo, 1978). Gruzelier and Hammond (1976), for example, showed that schizophrenics exhibit greater right ear advantages than nonschizophrenic subjects for verbal content identification.

Research with clinical as well as non-clinical subjects has helped to delineate the functions of the left and right systems in language and affect expression and recognition. When the elemental processes of language (propositional and nonpropositional speech) and affect (positive and negative) are assessed, it becomes apparent that both cerebral systems are involved in different degrees. This introduction has indicated that both cerebral systems interact functionally for affect and language processes.

General Summary

The basic premise of contemporary neural science is that behavior is the result of brain function. This implies that for the expression of a particular behavior, certain neural systems or pathways in the brain must be activated. Neural systems of the brain not only underlie motor behaviors such as breathing or walking, but also complex affective and cognitive behaviors such as emotion, learning, and thinking. Consequently, disturbances of affect or cognition can be viewed as disturbances of brain function (see Kandel, Schwartz, & Jessell, 1991).

This neuropsychological approach has been applied to the analysis of functional cerebral asymmetry for language. Studies correlating behavior change with lesion location have provided basic clinical findings essential for research in this area. For instance, Broca's aphasia (Kandel, et al., 1991) results from lesions to the inferior premotor regions of the left hemisphere. This aphasia consists of nonfluencies characterized by a sparsity of conversational speech (Geschwind, 1970, 1972; Kimura & Watson, 1989) and/or impaired word generation on confrontation tests similar to the Thurston Word Fluency Test (FAS) (Feyereisen, Verbeke-Dewitte, & Seron, 1986). Other lesion studies have since confirmed that the left hemisphere plays a dominant role in language production, grammaticism, and articulation (Benton, 1968; Boller, 1968; Bolter, Long, & Wagner, 1983; Miceli, et al., 1981; Pendleton, et al., 1982; Perret, 1974).

Modern psychology has continued to study functional cerebral asymmetry for language through a construct known as verbal fluency. Verbal fluency denotes individual differences in the accuracy and efficiency of performing tasks involving recall, identification, and production of phonemic or word stimuli (Martin, Loring, Meader, & Lee, 1990; Perlmuter, Tun, Sizer, McGlinchey, & Nathan, 1987). The most commonly used verbal fluency measure is the FAS test (Borkowski, et al., 1967). This time limited test entails asking subjects to produce as many words as possible which begin with a particular letter.

Functional cerebral asymmetry has been assessed through dichotic listening studies. The technique consists of the concurrent presentation of auditory stimuli to either ear. An ear advantage occurs when a heightened proportion of stimuli are identified from one ear (Bryden, 1978). Cerebral asymmetry can be cautiously inferred from ear advantage (see Springer, 1987). In conjunction with brain damage studies, this research has shown that subjects not manifesting language problems exhibit a REA (left functional asymmetry) for nonpropositional stimuli, while subjects exhibiting nonpropositional language problems show significantly less of this REA (Hiscock & Kinsbourne, 1980; Hugdahl & Anderson, 1987; Obrzut, et al., 1980; Obrzut, et al., 1981).

In support of this, Hagopian, et al. (1992) have found differences in performance on dichotic listening tasks as a function of reading-disability. Under nonfocused conditions, reading-disabled children exhibited a weaker REA than non reading-disabled children. When given focus left instructions, reading-disabled children unlike the non reading-disabled children showed no REA. These results suggest that reading-disabled children, possibly like lower fluency subjects, exhibit less functional asymmetry for language and are more adversely affected by attentional instructions. Whether subjects with learning disabilities are less verbally fluent than subjects not having learning disabilities has not been directly studied. Subjects in the present study were not asked whether they were told they had a learning disability as a child.

In sum, research has identified a greater REA for tasks related to the verbal fluency construct and a corresponding decrement on fluency tasks for subjects exhibiting left cerebral dysfunction. More extensive damage or dysfunction within the left cerebrum has been associated with greater fluency impairment on examination (Alexander, Benson, & Stuss, 1989; Damasio & Geschwind, 1984). Thus, subjects having a lower score on the FAS should exhibit less of a REA for nonpropositional speech than subjects having a higher score. We can hesitantly infer that this reduced left asymmetry for language production in lower fluent subjects is due to less usage of this system (Hunt, Lunneborg, & Lewis, 1975). Alternatively, a relative increase in the functional ability of the right cerebrum may result in a heightened advantage for tasks served primarily by those regions (e.g. left ear advantage for affective intonation in speech; and left hemi-attention - as might be measured by a focused left dichotic listening paradigm).

However, recent research has suggested that many aspects of language (intonation) are not a functional system of the left hemisphere, but are affected by the right hemisphere. This is especially the case for propositional speech, such as affective intonation and prosody (Borod, et al., 1986; Borod, et al., 1987; Diamond, et al., 1976; Gainotti, 1972; Harrison, Alden, Lanter, & Zicafoose, 1991; Kolb & Taylor, 1981; Levy, et al., 1983; McFarland & Kennison, 1989; Rinn, 1984; Sackheim & Grega, 1987; Sackheim, et al., 1978; Sergent, 1985).

While these studies may indicate a right hemisphere advantage for all forms of emotion (Gainotti, 1983; Ley & Strauss, 1986), other studies have suggested a functional advantage of the right hemisphere for negative (e.g. sad and angry) emotions, whereas bilateral or left hemisphere advantage has been reported for positive (e.g. happy) affective perception and/or expression (Harrison, Gorelczenko, & Cook, 1990; Silberman & Weingartner, 1986; Tucker, 1981). Davidson, et al. (1990), for instance, found that expressed disgust is associated with anterior regions of the right hemisphere and expressed happiness is associated with anterior regions of the left hemisphere. In addition to showing that subjects exhibit a left ear advantage (LEA) when identifying whether stimuli are affective or not (Ley & Strauss, 1986), research has documented a LEA for identifying negative and a REA for identifying positive affective tone (Bryden & MacCrae, 1989; Ley & Bryden, 1979; Suberi & McKeever, 1977).

These studies are congruent with the right-shift theory proposed by Annet and Kilshaw (1984) and supported by Hagopian et al. (1992). According to the right-shift theory, individuals manifesting language or reading problems suffer impairments in the left cerebral system and consequently overrely on the right cerebral system for these tasks. Thus, it seems reasonable to expect subjects having a lower FAS score to have a greater LEA for identification of angry and sad verbal stimuli than subjects having a higher FAS score.

These studies are also congruent with inhibition theories (Bakan, 1969; Galin, 1974; Kinsbourne, 1970; Tucker, et al., 1979). According to these theories, the left cerebral system plays an inhibitory role in affect expression and recognition. If individuals manifesting language or reading problems have impairments in the left cerebral system, then it seems reasonable to expect that the proposed inhibitory mechanisms of the left cerebral system would similarly be impaired. Thus, individuals having a lower FAS score might have fewer (less efficient) affective inhibitory mechanisms in the left cerebral system than subjects having a higher FAS score and would manifest a greater LEA for angry or sad verbal affect stimuli. Like affect recognition and expression, inhibitory processes are also believed to be functions of the anterior right and left cerebral systems (Tucker, 1981).

Cerebral asymmetry, within the general construct of language, can be construed as exhibiting nonpropositional components from the left and propositional or affective components from the right cerebral systems. Since verbal fluency is the primary index of verbal function, perception of propositional and nonpropositional speech should vary as a function of fluency classification. If the inference that subjects having a lower FAS score exhibit less of a REA for nonpropositional speech as a result of impairment of the left cerebral system is accurate, we expect them to show similar impairments for propositional speech. Specifically, subjects having a lower score on the FAS test should exhibit less of an REA for the perception of happy speech and possibly a greater LEA for the perception of angry or sad affective stimuli.

This experiment on affect perception used the dichotic listening paradigm to assess functional cerebral asymmetry for propositional and nonpropositional speech as a function of fluency. After being assigned to a fluency category, subjects listened to a series of four words (tower, dower, bower, power) spoken in four affective tones (neutral, angry, sad, happy). During Phase 1 (Nonfocused Dichotic Paradigm), subjects were not instructed to attend (intend) to the right or left ear. During Phase 2 (Focused Dichotic Paradigm), subjects were instructed to attend (intend) to either the left or the right ear. The nonfocused condition always came before the focused condition. Phase 1 and Phase 2 data were analyzed separately.

It was expected that accuracy of identification of propositional and nonpropositional speech would vary with ear of presentation and fluency classification. First of all, it was hypothesized that subjects lower in fluency would exhibit less functional cerebral asymmetry for nonpropositional speech, and to manifest less of an REA for nonpropositional speech than subjects higher in fluency. Secondly, if this reduced left asymmetry for nonpropositional speech in lower fluent subjects is due to left cerebral impairment, we hypothesized that subjects lower in fluency would show less of an REA for happy affective stimuli and a heightened LEA for sad or angry affective stimuli. Thirdly, we hypothesized that the identification of propositional and nonpropositional speech would vary as a function of ear of focus or intention. In sum, we hypothesize that there will be main effects of verbal fluency (lower, middle, and higher), stimulus type (word or affect), and intention (focus right or focus left).

Method

Subjects

Forty-eight right-handed subjects were recruited from the departmental undergraduate subject pool (the average age range was between 19 years and 23 years). Three of these subjects were discarded because they were left handed, reported experiencing a head injury, reported being hospitalized, reported that English was a second language, or was interrupted during the testing. Similarly, only subjects with normal auditory acuity for their age group for pure-tones were used in the analysis. All subjects tested had thresholds less than 20 db and no subjects were discarded due to hearing difficulties. The remaining forty-five subjects responses were used in the analysis of Phase 1. Also, in order to have an equal number of five subjects in each of the fluency by focus groups of Phase 2, the data from 15 subjects was discarded in a random manner. The research was devised in accordance with the guidelines of the Human Subjects Committee and Institutional Review Board of Virginia Polytechnic Institute. All subjects received extra credit for participation and signed an informed consent form (Appendix A).

Apparatus

Each subject was tested individually throughout the day, between the hours of 8 am and 5 pm, in a comfortably lit (about 1400 lx) room with ambient noise levels of approximately 45.00 $\pm$ 0.32 db spl (re. 0.002 dynes/cm^2, A scale). Light levels were determined by the use of a Realistic Luminescence Meter. Sound levels were determined by the use of a Metrosonics db 307 Noise Dosimeter.

Subjects were tested by one of two experimenters. One experimenter was a female graduate student, while the other was a male undergraduate honor's student. Before beginning the study, six pilot subjects completed the experimental procedure with both experimenters in order to make sure that procedures were accurately followed. These pilot subjects consisted of friends of the experimenters and were not included in the final analysis.

Auditory acuity was assessed by a pure-tone test using the Qualitone Acoustic Appraiser (Model WR-C) and lightweight portable Qualitone TD-39 headphones. To be included in the study, subjects were required to have an average hearing threshold level (HTL) of 20 db or less for all of the critical speech frequencies tested. A decibel (db), one-tenth of a bel, is a unit used to denote intensity or amplitude of a sound wave (Schiffman, 1990). A bel is the log of the ratio of the reference pressure divided by the standard pressure (0.0002 dynes/cm^2) (Schiffman, 1990). The auditory acuity criterion was based on the normative research with college students of Stelmachowicz, Beauchaine, and Jesteadt (1989), and Stevens, Berkovitz, Kidd, Kalberer, and Green (1987) which reported thresholds greater than 20 db to be a sign of auditory impairment. None of the subjects in this study showed threshold levels greater than 10 db for any of the frequencies tested.

Verbal fluency was assessed by the FAS test. Developed by Borkowski, et al. (1967), the FAS test was used to determine the number of words which could be generated by the subject beginning with letters spoken by the experimenter for a three minute period. The FAS test is also known as the Controlled Oral Word Association Test (see, Huntzinger & Harrison, 1992). Three letters, "F", "A", and "S" were used. The subject was given one letter per trial and asked to name as many words as possible that started with the letter over a 60 second interval. This interval length was the same as that used by Borkowski et al. (1967). The same word having a different ending, proper names, and numbers were not counted. The subjects score was the total number of acceptable words produced across the three trials for the three letters. Based on the scores obtained, subjects were categorized as exhibiting lower, middle, or higher levels of verbal fluency. Analysis, scoring, and assignment to groups based on these tests was identical to previously used procedures (Perlmuter, et al., 1987). The 15 highest fluency scores, which ranged from 42 to 57, made up the higher fluency group. The 15 lowest fluency scores, which ranged from 18 to 31, made up the lower fluency group. The 15 fluency scores ranging from 32 to 41 made up the middle fluency group.

Functional cerebral asymmetry was assessed using the Dichotic Emotional Words Tape developed by Bryden and MacCrae (1989). This tape consisted of four words (tower, dower, bower, and power) spoken by a male voice under four affective conditions (neutral, angry, sad, and happy). These 16 items were digitally produced on a PDP 11/40 computer, equalized for decibel level, and edited to an average duration of 500 ms. Validity of the affective conditions was determined by the ratings of 20 naive subjects. These subjects were able to identify which affect was being portrayed, in all of the trials on the tape, ninety-six percent of the time. Order of presentation was completely counterbalanced. There were 10 second breaks following every 18 trials and 3 second lapses between each trial. The tape consisted of 144 trials with one of the four affect conditions and one of the four words occurring on each of the trials. Refer to Appendix B for a listing of stimulus pairs. For every other subject head phone placement was reversed to insure headphone equality.

Procedure

Before asking subjects to sign the informed consent form, subjects were given the following introduction:

"This is a study of auditory processing which involves three tests. The first test is designed to determine the softest possible sounds that you can hear for tones critical to speech. The second test is a verbal fluency test, which like impromptu speaking, is designed to determine how well you think on your feet verbally. The third test, which will take up most of the time, is a dichotic listening test. During this test you will hear different things spoken into each ear and I will ask you to listen for different things."

Auditory acuity testing began after this introduction. After removing the cover, plugging in the power chord and ear phones, setting the HTL dials to 0 db, the experimenter turned the apparatus on. Subjects were seated with the experimenter and acoustic appraiser behind them. The experimenter asked the subjects how old they were, whether they heard well on the telephone, whether they wore a hearing aid, and if they have ever had any history of hearing problems (e.g. tubes in the ears or infections), experienced a major illness or head injury, or been hospitalized. The experimenter recorded this information on the form, refer to Appendix C.

Subjects were given the following instructions by the experimenter:

> "This test is designed to determine the softest possible sounds that you can hear. I am first going to test your right ear. When you hear a tone in your right ear, I want you to raise your right hand and keep it up until you no longer hear the tone. After a while I will stop the test and tell you that I am now going to test the left ear. At this point I want you to repeat the procedure for your left ear. Any questions?"

Once these instructions were given, subjects were asked to remove glasses or earrings and put on the headphones. For every other subject headphone position was reversed. Auditory acuity testing was began using the ascending method of limits. Testing of the right ear preceded the left ear, using a procedure identical to that used by Stelmachowicz, et al. (1989).

To test the right ear, the channel button and channel switch were pushed to the right. After pushing the 1000 hertz button and setting the right HTL button at 5 db, the right tone interrupter button was pushed to turn on the tone. The right HTL button was increased in decrements of 5 db until the subject raised his/her right hand and then decreased in decrements of 5 db until the subject put their right hand down. The dial was then increased in decrements of 5 db until the subject again raised their right hand and this decibel level was recorded on the form as the HTL for that frequency.

Once the subject's HTL for 1000 hz was determined, other thresholds for frequencies critical to speech detection were tested (Stelmachowicz, Beauchaine, and Jesteadt, 1989). In their respective order, the following frequencies were tested and responses recorded: 1000 hz, 1500 hz, 2000 hz, 3000 hz, 1000 hz, 750 hz, and 500 hz.

To test the left ear, the channel button and channel switch were pushed to the left. After pushing the 1000 Hz button and setting the left HTL button at 5 db, the left tone interrupter button was pushed to turn on the tone. Thresholds were tested in the same order as was the right ear.

Once this auditory acuity testing was completed, verbal fluency testing began by giving each subject the following instructions:

> "I will say a letter of the alphabet and I want you to say as fast as you can all the words you can remember that start with that letter. For example, if I say "L", you might say "life, laugh, love ..." or other words like that. I do not want you to say words that are proper names (words that start with a capital letter), such as "London, Lincoln, or Larry." Also do not say the same word over with a dissimilar ending, such as "leap" and "leaping." Do you have any questions? Okay, start when I speak the letter. The first letter is "F". Begin."

Timing began at once, with one minute allowed for each letter. If the subject ceased to respond before the end of the minute, they were prompted to attempt to remember more words. If there was 15 seconds of silence, the above instructions and the letter were recommended; however, no expansion of the time limit was made if the instructions were restated during the evaluation. After the first minute, the test was repeated with the letters "A" and "S" and one minute was given for each. The subject's answers were recorded on cassette tape and scored on the basis of the total number of admissible responses made during the three minute interval.

Once the FAS test was completed, the test for functional cerebral asymmetry for affect perception began. The procedure for this part of the study was identical to that used by Bryden and MacCrae (1989). The dichotic stimulus tape was played at 75 db through headphones from the Qualitone Acoustic Appraiser to subjects from each of the fluency categories. Subjects were asked to identify, as quickly as possible, whether or not a specified target word occurred in one block of trials and whether or not a specified emotional tone occurred in the next block of trials. Since each subject was instructed (specified) to listen for only one affective tone and one word, four subjects were needed for all of the affective tones and words to be used as targets.

Stimulus presentations were completely counterbalanced based on order of arrival. Each target word and target affective tone was assigned a number. Refer to Appendix D for a listing of these numbered stimulus pairs. As subjects arrived, they were given a number. For instance, the fourth subject tested was called Subject 4 and was exposed to Pair 4. Subjects having an even subject number were asked to identify the target word from the assigned pair in Block 1 and Block 3 and the target emotional tone from the assigned pair in Block 2 and Block 4. Subjects having an odd subject number were asked to identify the target emotional tone from the assigned stimulus pair in Block 1 and Block 3 and the target word from the assigned stimulus pair in Block 2 and Block 4. In addition, head phone placement was reversed for every other subject.

Before the actual test began, two practice tests were given. On the first practice test, subjects were exposed to nine dichotically presented syllables. While referring to a stimulus card with all of the syllables which were to be presented, the experimenter gave the following instructions:

> "When I switch on the tape, you will hear several different syllables in each ear. The syllables are (referring to the stimulus card): pa, ba, ga, and ka. If you think you hear the syllable ga, say yes. If you do not think you hear the syllable ga, I want you to say no. Any Questions?"

After responding to any questions, the experimenter started the tape and recorded a "y" next to the trial numbers where subjects responded yes and an "n" next to the trials whereby the subject responded no. The stimulus card was in front of the subject throughout the practice test.

Once this was finished, the second practice test was given. While again pointing to the stimulus card, subjects were given the following instructions:

"When I switch on the tape, you will hear several different words spoken in several different tones of voice. The words are (referring to the stimulus card): Bower, dower, power, and tower. The tones of voice are (referring to the poster): Happy, sad, angry, and neutral. If you hear a word spoken in the emotional tone (happy, sad, angry, or neutral), I want you to say yes. If you do not think you hear a word spoken in the emotional tone (happy, sad, angry, or neutral), I want you to say no. Any questions?"

After responding to any questions, the experimenter started the tape and again recorded a "y" next to the trial numbers where the subject responded yes and an "n" next to trials whereby the subject responded no. The stimulus card was in front of the subject for this practice test.

During Phase 1, subjects received all four blocks without being instructed to attend (intend) or focus on a particular ear. Instructions for the word identification blocks in Phase 1 were as follows:

> "I want you to pay close attention. If you think you hear the word (bower, dower, power, or tower), I want you to say yes. If you do not think you hear the word (bower, dower, power, or tower), I want you to say no. Any questions?"

Instructions for the affective tone identification Blocks in Phase 1 were as follows:

> "I want you to pay close attention. If you think you hear the emotional tone (happy, sad, angry, or neutral) I want you to say yes. If you do not think you hear the emotional tone (happy, sad, angry, or neutral), I want you to say no. Any questions?"

During Phase 2, subjects received the same stimulus blocks as in Phase 1 and were told to either focus (attend) left or focus (attend) right. If the subject had an even subject number, they were told to focus right and raise their right hand if they thought they heard the target stimulus. If the subject had an odd subject number, they were told to focus left and raise their left hand if they thought they heard the target stimulus. The hand that subjects were instructed to raise was always on the same side as the ear of focus. Instructions for the word identification Blocks in Phase 2 were as follows:

> "I want you to pay close attention to your (right or left) ear. If you think you hear the word (bower, dower, power, or tower), I want you to raise your (right or left) hand and say yes. If you do not think you hear the word (bower, dower, power, or tower), I want you to keep your (right or left) hand down and say no."

Instructions for the affective tone identification Blocks in Phase 2 were as follows:

> "I want you to pay close attention to your

(right or left) ear. If you think you hear the emotional tone (happy, sad, angry, or neutral), I want you to raise your (right or left) hand and say yes. If you do not think you hear the emotional tone (happy, sad, angry, or neutral), I want you to keep your (right or left) hand down and say no."

For both Phase 1 and Phase 2, the experimenter recorded a "y" next to the trial numbers where subjects responded yes and an "n" next to the trial numbers where subjects responded no. Subjects received eight scores per Block. For each of these scores, a total of nine was the highest possible. If subjects were asked to identify a particular affect, the total number of correct identifications for each of the words in each ear was recorded. If subjects were asked to identify a particular word, the total number of correct identifications for each of the affects in each ear was recorded.

Results

The data from three subjects were not used in the final analysis. The first subject whose data were discarded was left-handed and reported experiencing a head injury. The second subject whose data were discarded was an international student with English as a second language. The third subject whose data were discarded was a subject who during the fluency testing was disrupted by someone entering the lab.

Data was analyzed using MANOVA's as opposed to ANOVA's to control for experimentwise error and variance from two dependent variables. Experimentwise error occurs when effects come out significant because the more statistics run on the same set of data the more likely one will come out due to chance alone. Rather than performing two ANOVA's for each hypothesis, one for the REA scores and one for the LEA scores, one MANOVA can be performed to reduce the number of tests run. In addition, the MANOVA performs two ANOVA's, however, these ANOVA's for each dependent variable take into account variance in scores caused by the other dependent variable. Results using ANOVA's and MANOVA's were identical in all cases in the present study, however, since the MANOVA reduces experimentwise error and controls for variance due to the other dependent variable, it was used.

A two-way mixed factorial MANOVA with the between subjects factor of Verbal Fluency (VF) (higher, middle, and lower) and the repeated measures factor of Stimulus Type (word and affect) was performed on the data from Phase 1. This was performed to assess Hypothesis 1, which proposed that lower fluency subjects would exhibit less of an REA for nonpropositional speech than subjects higher in fluency. Dependent measures were the total number of correct identifications of stimuli presented to the left ear (LEA) and the total number of correct identifications of stimuli presented to the right ear (REA). Refer to Appendix E for the raw data and Appendix F for the MANOVA and descriptive statistic tables. Tukey's significant difference test (HSD) ($p < 0.05$) was used for all post hoc comparisons of means in this study.

The main effect of Group, $F(2,42) = 3.86$, $p = 0.0288$, and of Stimulus Type, $F(1,42) = 14.63$, $p = 0.0004$ were significant using the LEA scores. There was no significant interaction. Tukey's HSD post hoc comparison revealed that higher VF subjects (M = 14.00; SD = 3.17) identified significantly more total stimuli presented to the left ear than the lower VF subjects (M = 11.50; SD = 4.49), and subjects middle in fluency (M = 13.23; SD = 3.00) did not significantly differ from the other fluency groups. Refer to Figure 1. In addition, Tukey's HSD post hoc comparison revealed that the total number of correct responses for stimuli presented to the left ear was greater for the identification of affect (M = 14.36; SD = 3.21) than for the identification of words (M = 11.47; SD = 4.09). Refer to Figure 2.

The main effect of Group, $F(2,42) = 7.59$, $p = 0.0015$, and Stimulus Type, $F(1,42) = 6.26$, $p = 0.0163$, were also significant using the REA scores. There were no significant interactions. Tukey's HSD post hoc comparison revealed that lower VF subjects (M = 11.23; SD = 4.42) identified significantly fewer stimuli presented to the right ear than both the middle VF (M = 13.93; SD = 3.81) and higher VF (M = 14.87; SD = 3.28) subjects. Refer to Figure 3. In addition, Tukey's HSD post hoc comparison revealed that the total number of correct responses for stimuli presented to

Figure 1. Total correct for the left ear as a function of verbal fluency classification.

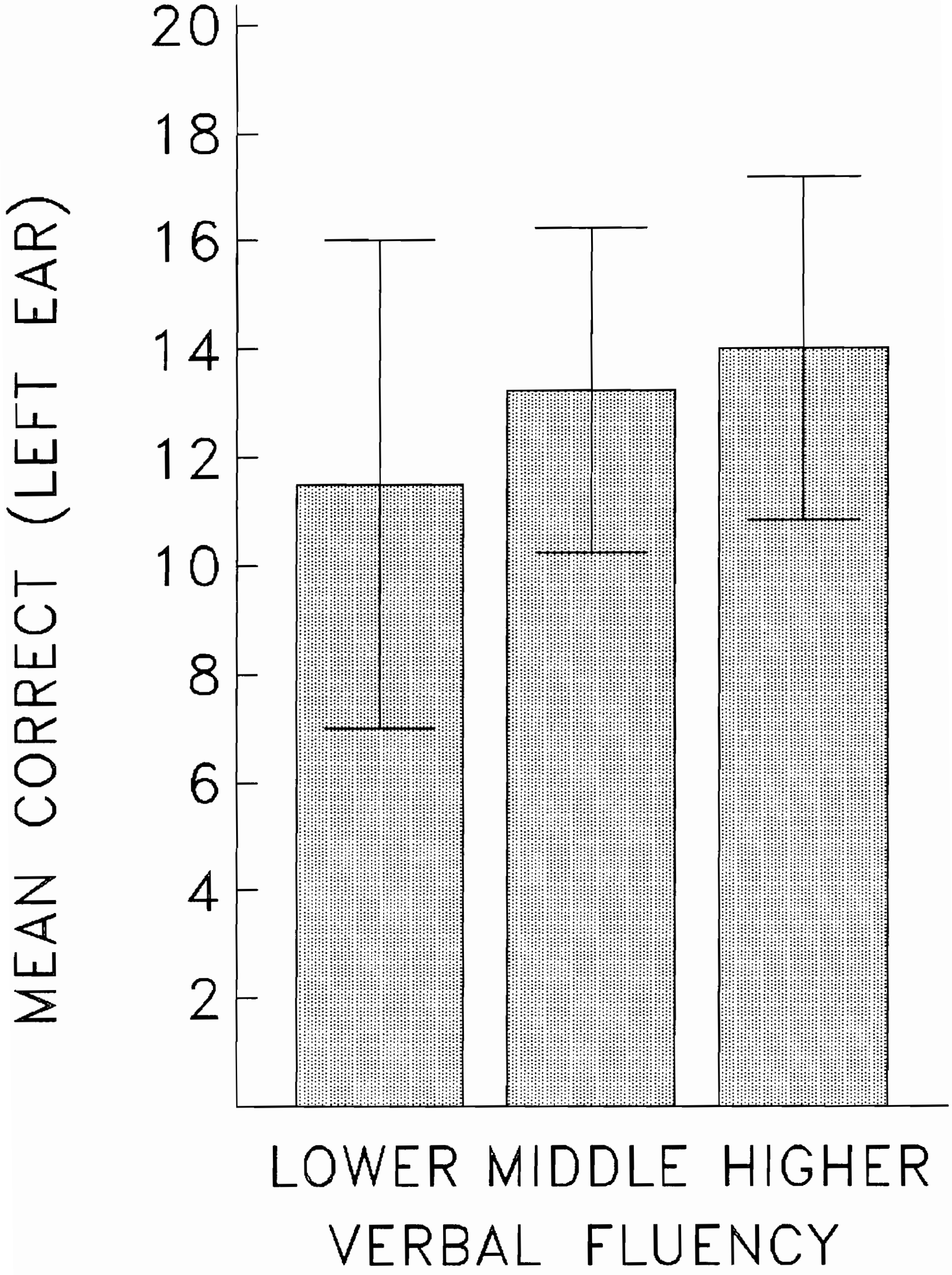
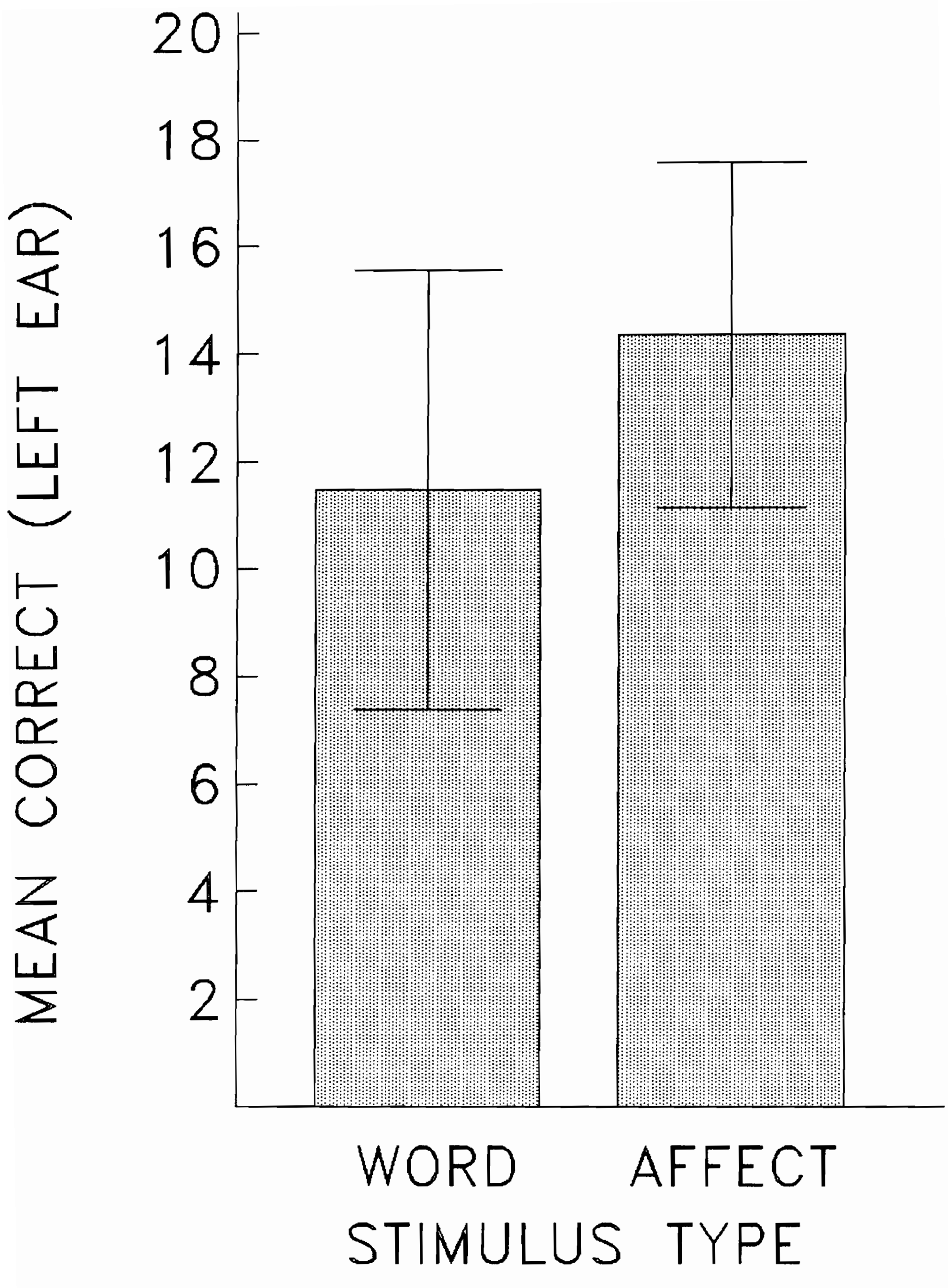
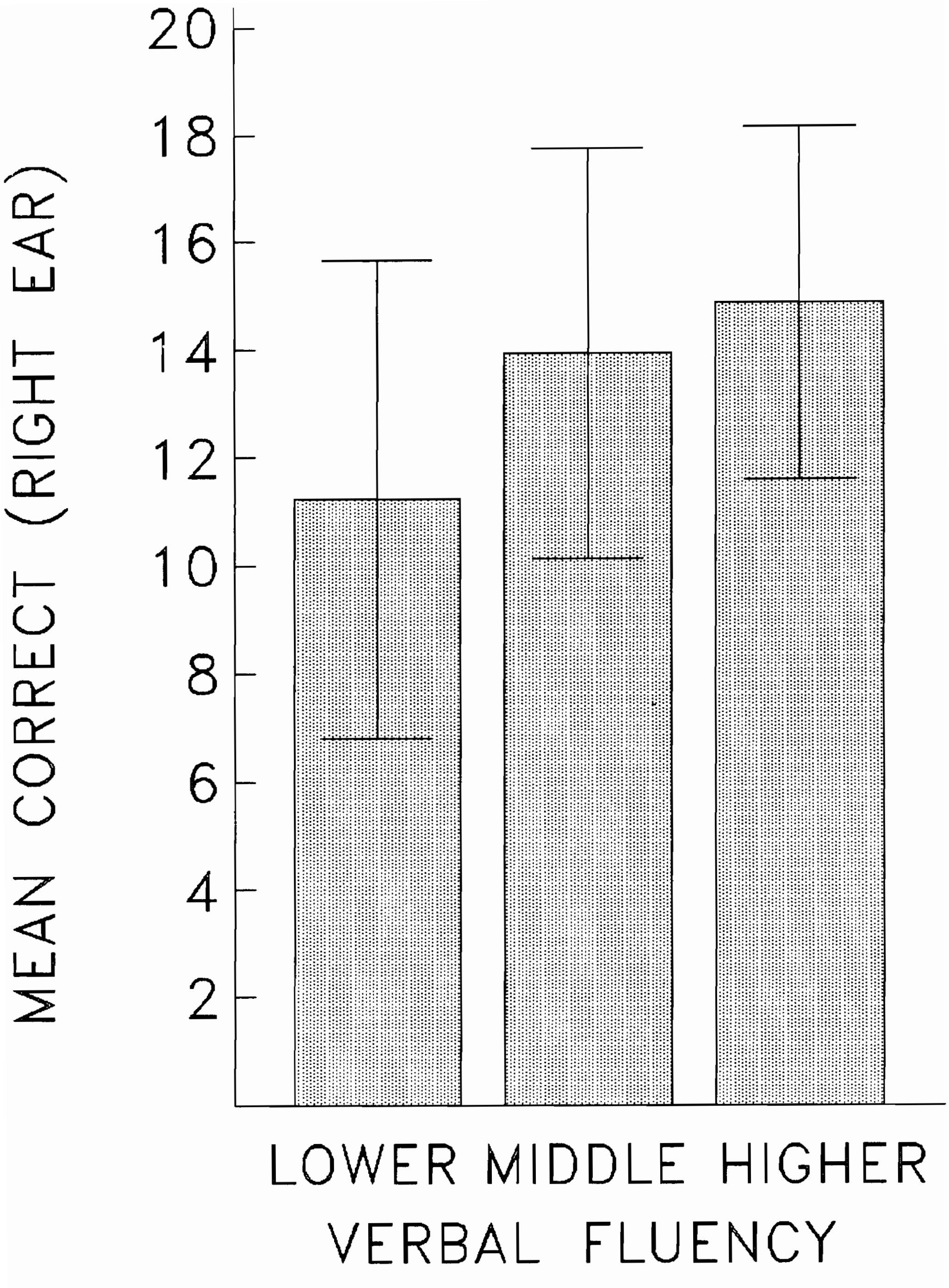

MEAN CORRECT (LEFT EAR)
20
18
16
14
12
10
8
6
4
2
LOWER MIDDLE HIGHER
VERBAL FLUENCY

Figure 2. Total correct for the left ear as a function of stimulus type.



MEAN CORRECT (LEFT EAR)
20
18
16
14
12
10
8
6
4
2
WORD
AFFECT
STIMULUS TYPE

Figure 3. Total correct for the right ear as a function of verbal fluency classification.



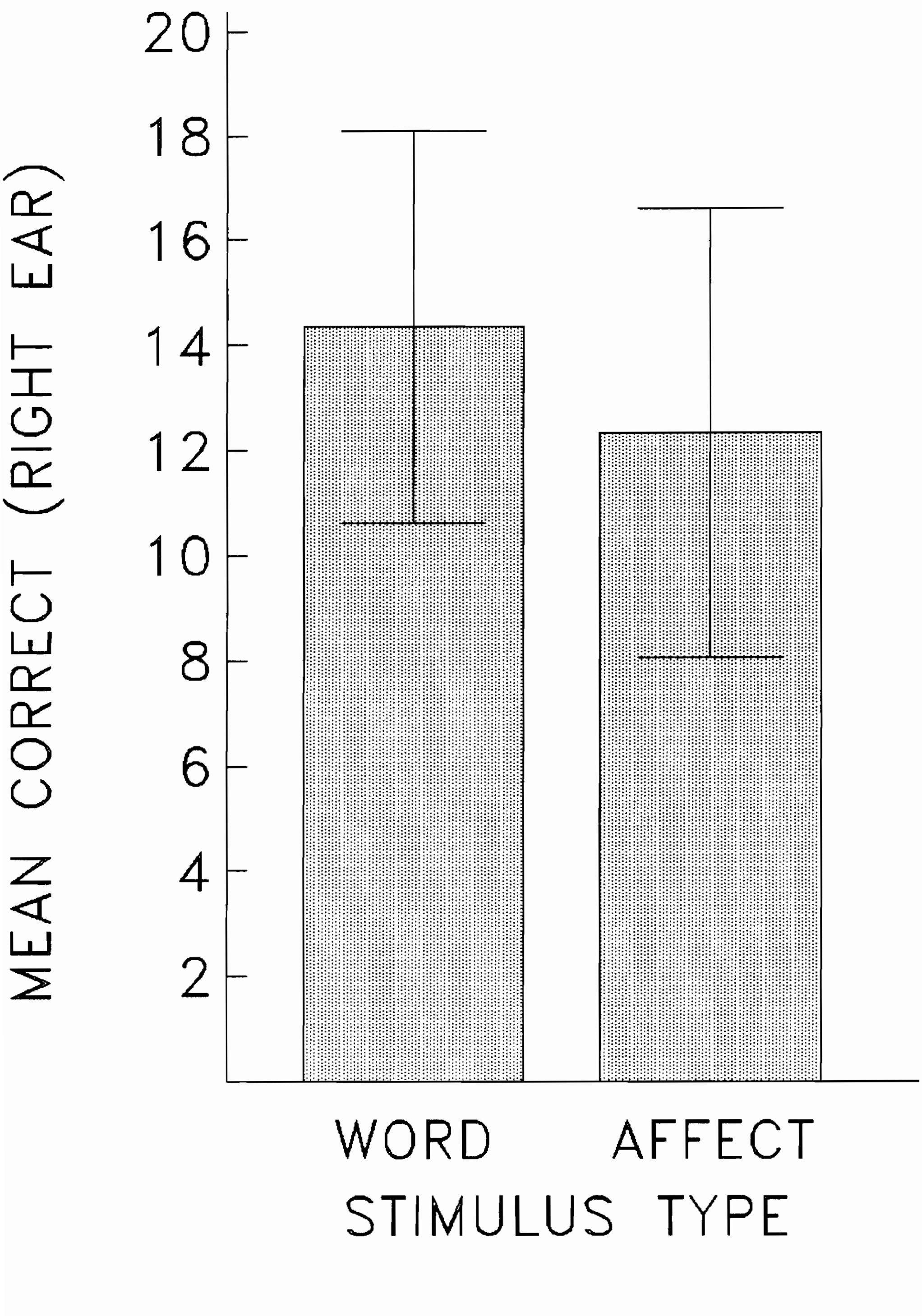
20
18
16
14
12
10
8
6
4
2
MEAN CORRECT (RIGHT EAR)
LOWER
MIDDLE
HIGHER
VERBAL FLUENCY

the right ear was greater for the identification of words ($\underline{M}$ = 14.36; $\underline{SD}$ = 3.75) than for the identification of affect ($\underline{M}$ = 12.33; $\underline{SD}$ = 4.27). Refer to Figure 4.

A two-way mixed factorial MANOVA with the between subjects factor of Fluency (higher, middle, and lower) and the repeated measures factor of Affect (happy, sad, angry, and neutral) was performed on the data from Block 1 or Block 2 from Phase 1. Whether subjects listened for a particular word or particular affect is completely counterbalanced between Block 1 and Block 2. Types of affect in Phase 1 can only be assessed in the block where the subject was asked to listen for a particular word. This analysis was performed to assess Hypothesis 2, which proposed that subjects lower in fluency would exhibit less of an REA for happy stimuli and more of an LEA for angry or sad stimuli. Like the previous analysis, the dependent measures were the LEA and REA scores. Refer to Appendix G for the raw data and Appendix H for the MANOVA and descriptive statistic tables.

There were main effects of both Group, $F(2,42)$ = 5.41, $\underline{p}$ = 0.0081, and Affect, $F(3,126)$ = 7.75,

Figure 4. Total correct for the right ear as a function of stimulus type.

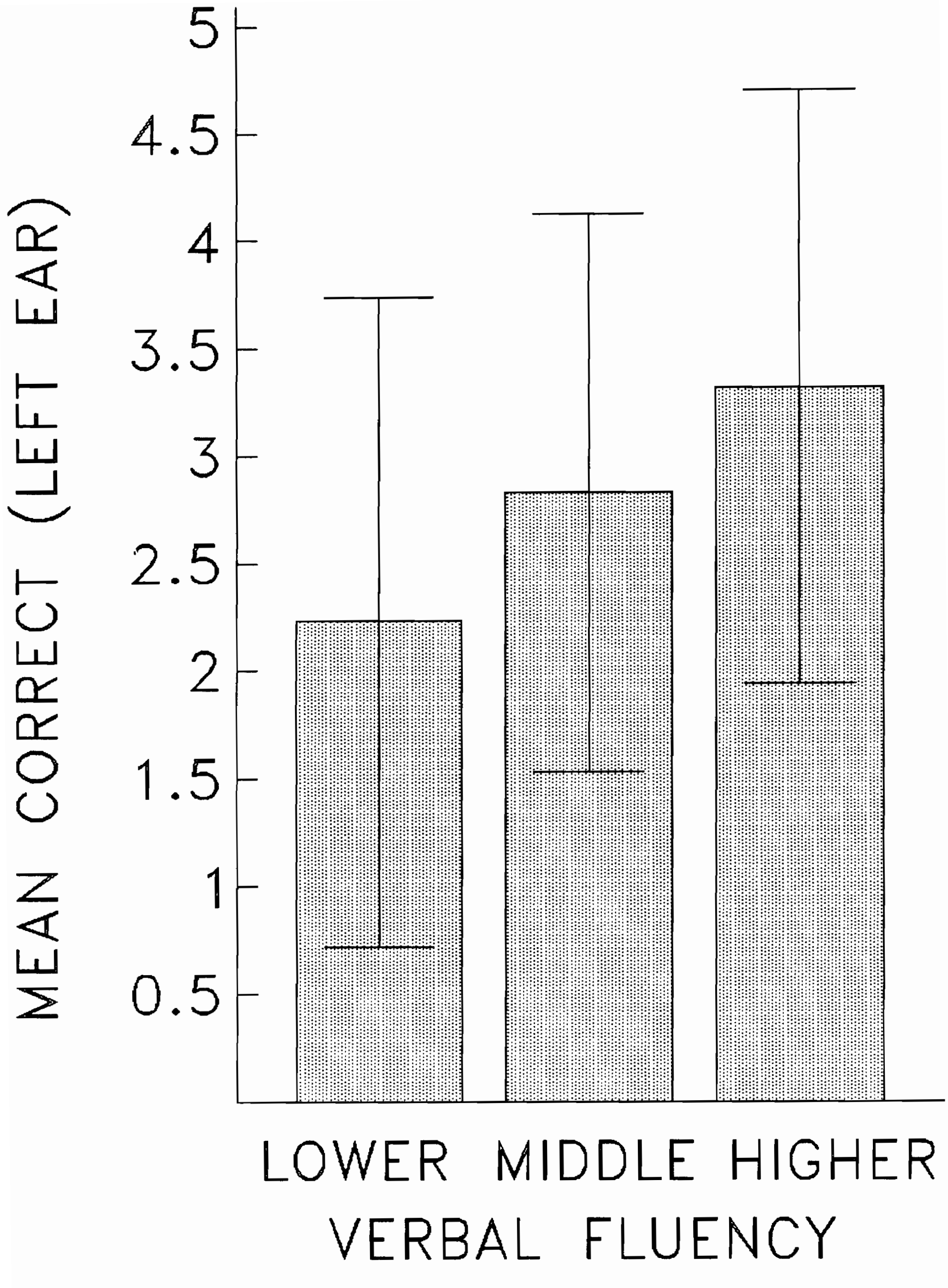

MEAN CORRECT (RIGHT EAR)
20
18
16
14
12
10
8
6
4
2
WORD
AFFECT
STIMULUS TYPE

$p = 0.0001$, for the LEA scores. There were no significant interactions. Tukey's HSD post hoc comparison revealed that the total correct for the left ear for higher VF subjects ($M = 3.32$; $SD = 1.38$) was significantly greater than the total correct for the left ear for lower VF subjects ($M = 2.23$; $SD = 1.51$), and the middle fluency group ($M = 2.83$; $SD = 1.30$) did not significantly differ from the other fluency groups. Refer to Figure 5.

In addition, Tukey's HSD post hoc comparison revealed that both the neutral ($M = 3.36$; $SD = 1.40$) and sad ($M = 2.93$; $SD = 1.34$) affect conditions produced a greater number correct for the left ear than the happy affect condition ($M = 2.11$; $SD = 1.65$). The angry affect condition ($M = 2.78$; $SD = 1.50$) did not significantly differ from the other affect conditions. Refer to Figure 6.

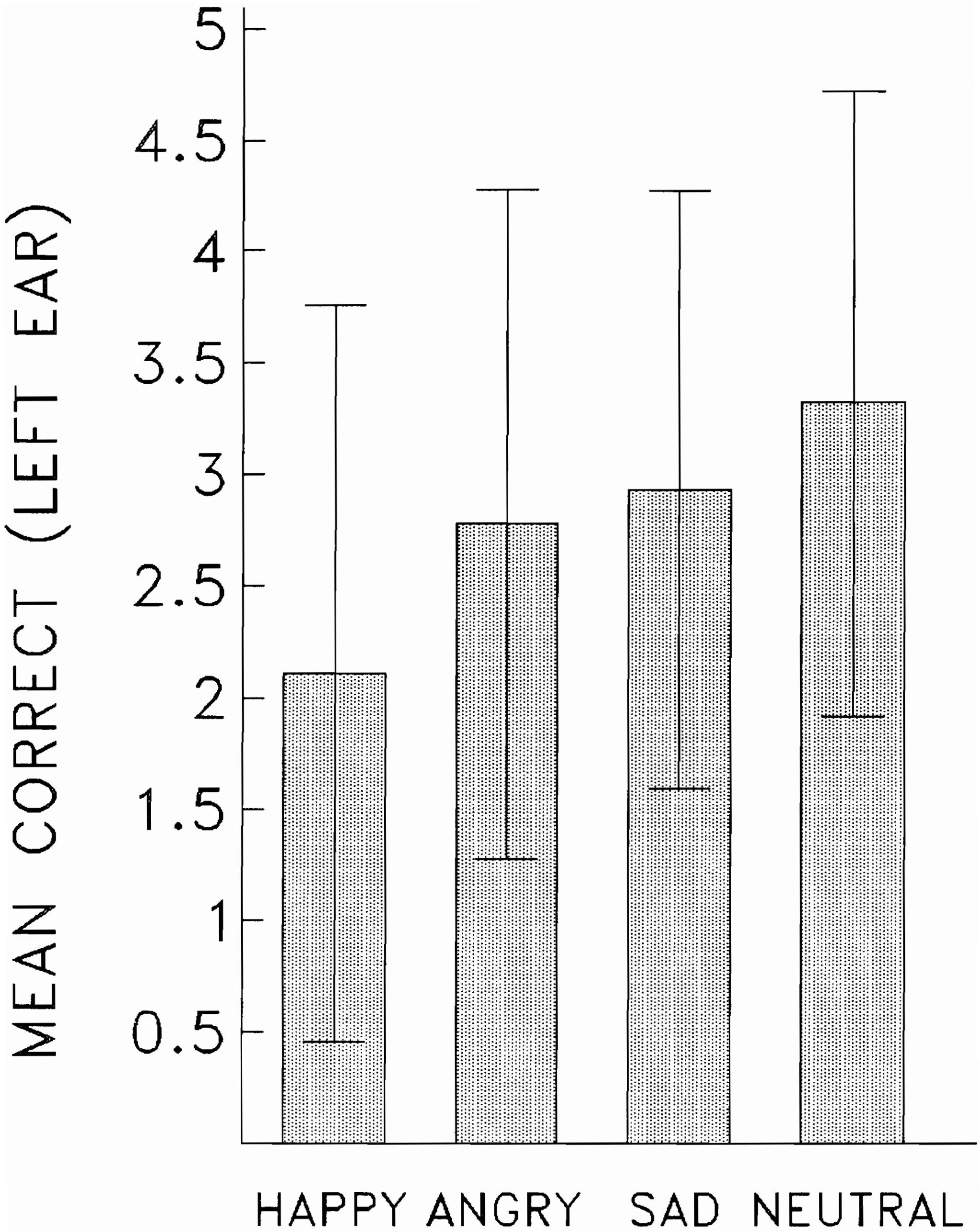
Not only was there a Group x Affect interaction, $F(6,126) = 2.88$, $p = 0.0116$, for the REA scores, there were also main effects of both Group, $F(2,42) = 3.91$, $p = 0.0278$, and Affect, $F(3,126) = 9.64$, $p = 0.0001$. Tukey's HSD post hoc comparison revealed that the identification of stimuli presented to the right ear

Figure 5. Total correct for the left ear as a function of verbal fluency classification.



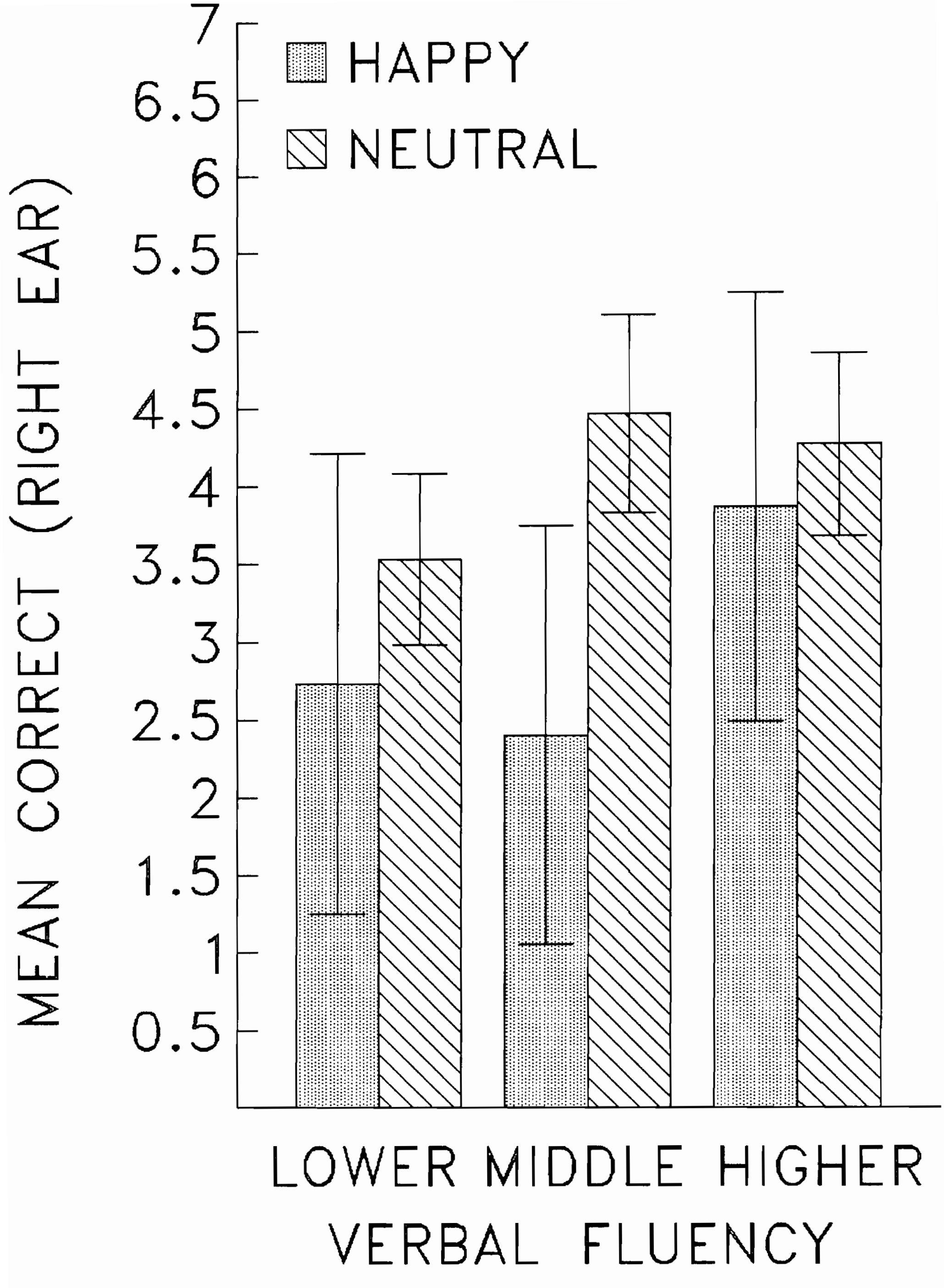
MEAN CORRECT (LEFT EAR)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
LOWER MIDDLE HIGHER
VERBAL FLUENCY

Figure 6. Total correct for the left ear as a function of affect.


MEAN CORRECT (LEFT EAR)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
HAPPY
ANGRY
SAD
NEUTRAL

was significantly less for both middle VF (M = 2.40; SD = 1.35) and lower VF (M = 2.73; SD = 1.44) subjects listening for happy than for both higher VF (M = 4.27; SD = 0.59) and middle VF (M = 4.47; SD = 0.64) subjects listening for neutral. Refer to Figure 7. Likewise, Tukey's HSD post hoc comparison showed that the total correct for the right ear for higher VF subjects (M = 3.97; SD = 1.09) was significantly greater than the total correct for the right ear for lower VF subjects (M = 3.08; SD = 1.57). The middle fluency group (M = 3.70; SD = 1.20) did not significantly differ from the other fluency groups. Refer to Figure 8. Tukey's HSD post hoc comparison also revealed that the total correct for the right ear was significantly greater for the neutral condition (M = 4.09; SD = 0.92) than either the sad (M = 3.53; SD = 1.50) or the happy (M = 3.00; SD = 1.49) affect conditions. Moreover, the angry affect condition (M = 3.71; SD = 1.16) produced a significantly greater total correct for the right ear than the happy affect condition (M = 3.00; SD = 1.49). Refer to Figure 9.

Figure 7. Total correct for the right ear as a function of affect and verbal fluency classification.



HAPPY
NEUTRAL
MEAN CORRECT (RIGHT EAR)
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
LOWER MIDDLE HIGHER
VERBAL FLUENCY

Figure 8. Total correct for the right ear as a function of verbal fluency classification.

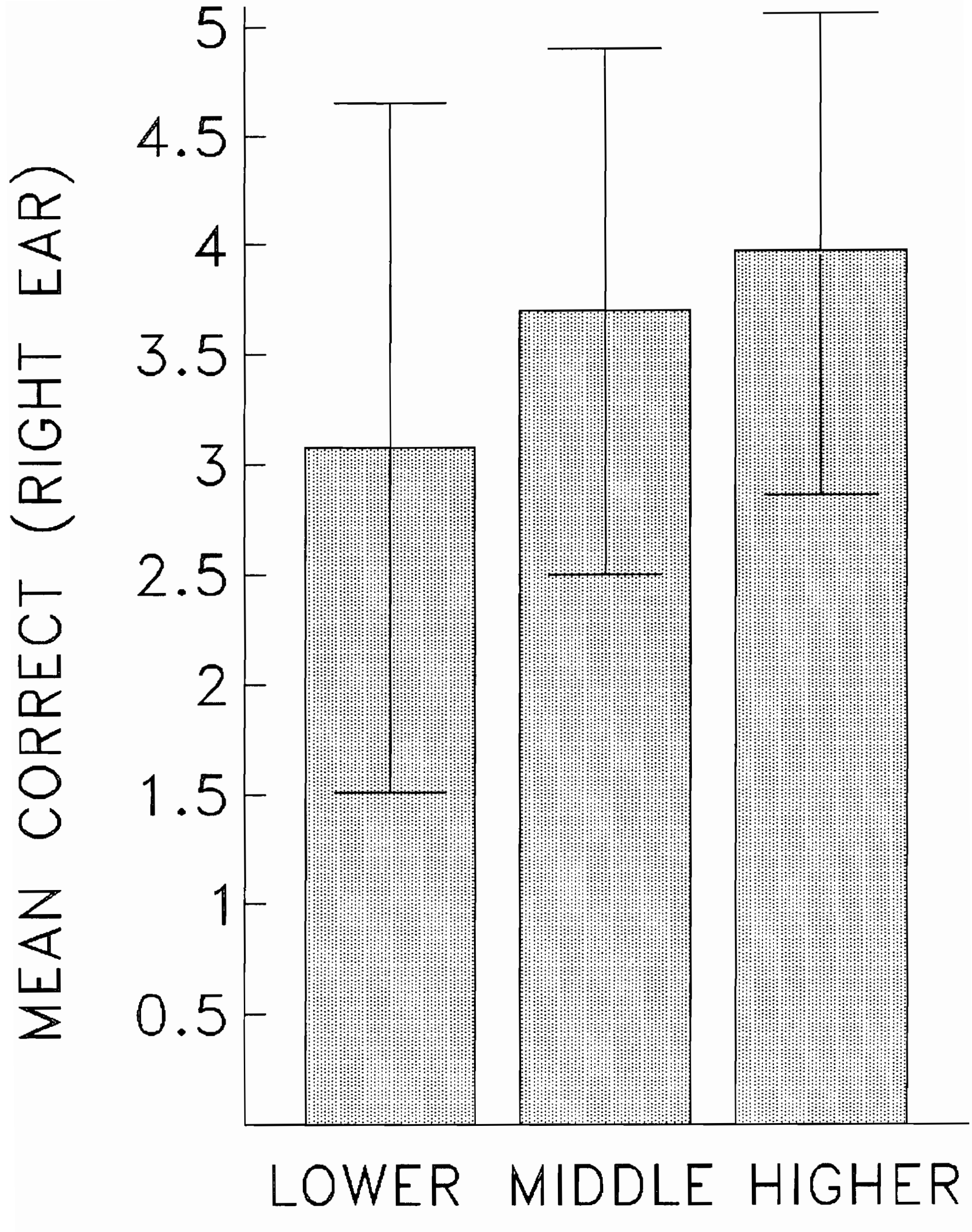
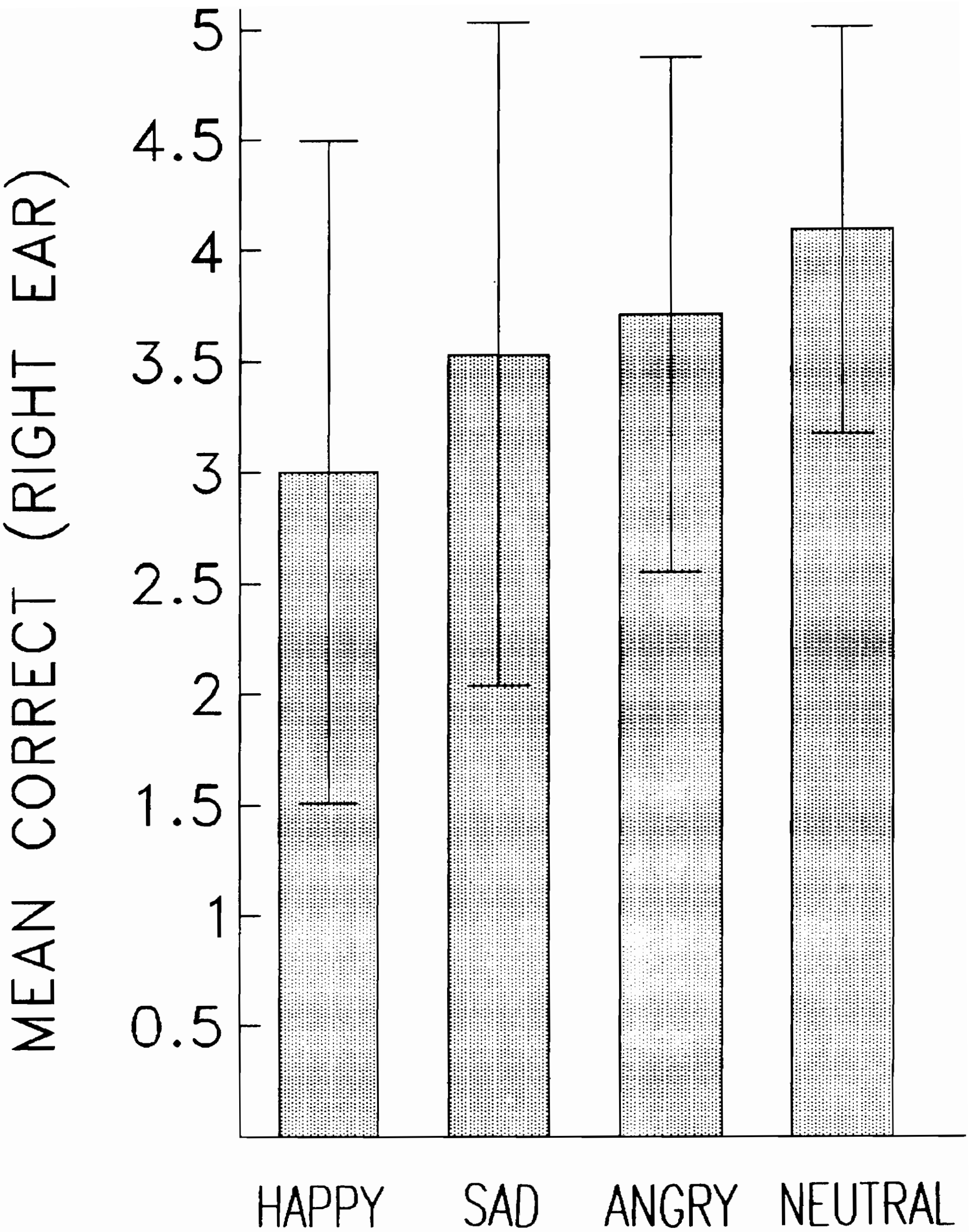

MEAN CORRECT (RIGHT EAR)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
LOWER
MIDDLE
HIGHER
VERBAL FLUENCY

Figure 9. Total correct for the right ear as a function of affect.


MEAN CORRECT (RIGHT EAR)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
HAPPY
SAD
ANGRY
NEUTRAL

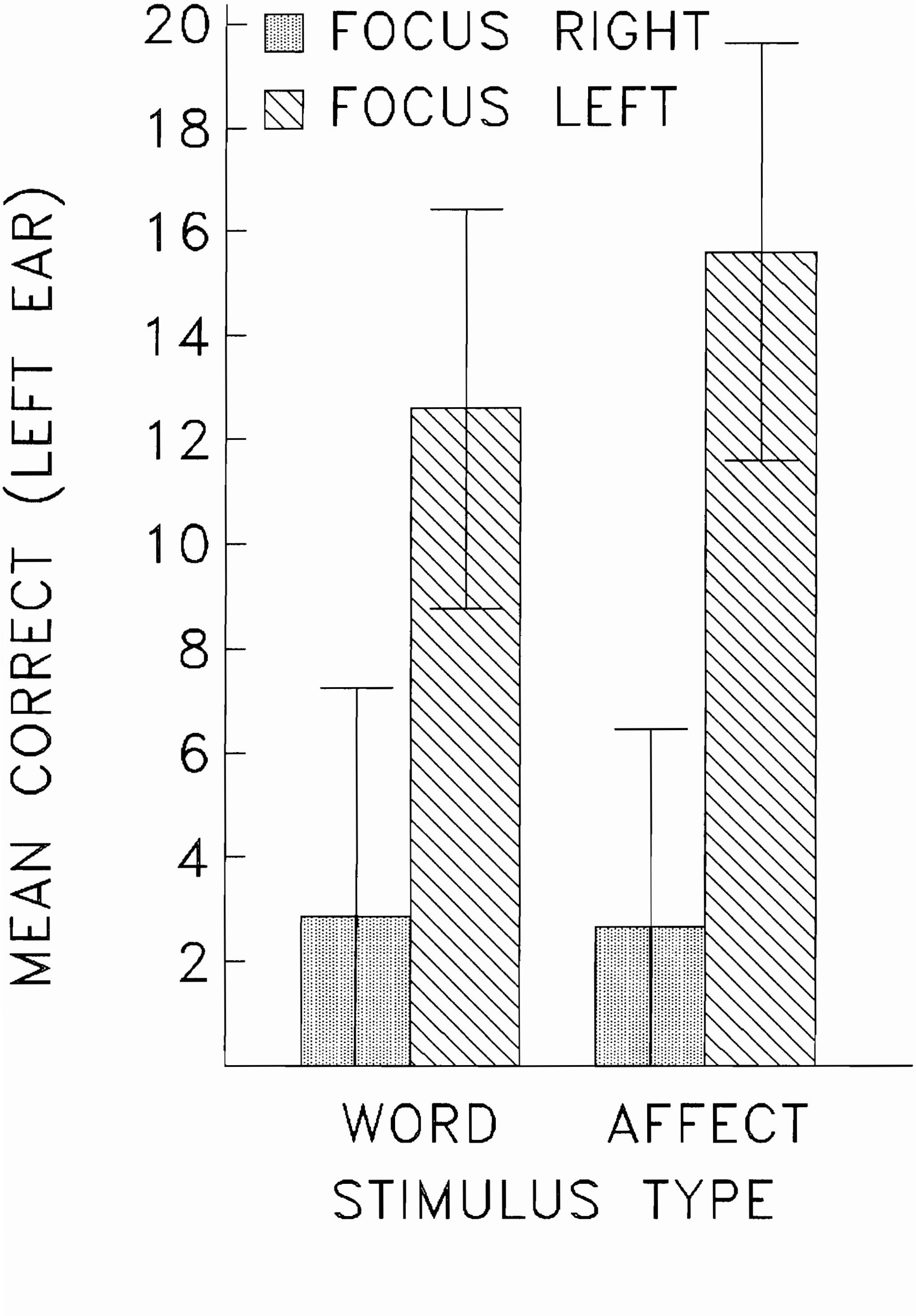
A three-way mixed factorial MANOVA with the between subjects factors of Fluency (higher, middle, and lower) and Focus (focus left or focus right) and the repeated measures factor of Stimulus (word or affect) was performed on the data from Phase 2 with five subjects per cell. This was performed to test Hypothesis 3, which proposed that REA and LEA scores would vary as a function of focus. Like the previous analysis, REA and LEA scores were used as dependent measures. Refer to Appendix I for the raw data and Appendix J for the MANOVA and descriptive statistic tables.

In addition to a significant Focus x Stimulus Type interaction, $F(1,24) = 6.25$, $\underline{p} = 0.0196$, there were main effects of both Focus, $F(1,24) = 71.03$, $\underline{p} = 0.0001$, and Stimulus Type, $F(1,24) = 4.79$, $\underline{p} = 0.0386$, using the LEA scores. Tukey's HSD post hoc comparison revealed that subjects in the focus left / word identification condition ($\underline{M} = 12.6$; $\underline{SD} = 3.83$) had a greater total correct for the left ear than subjects in both the focus right / word identification ($\underline{M} = 2.87$; $\underline{SD} = 4.38$) and focus right / affect identification ($\underline{M} = 2.67$; $\underline{SD} = 3.79$) conditions.

Likewise, the HSD revealed that subjects in the focus left / affect identification ($\underline{M}$ = 15.60; $\underline{SD}$ = 4.01) condition had significantly greater total correct for the left ear than subjects in both the focus right / word ($\underline{M}$ = 2.87; $\underline{SD}$ = 4.38) identification and the focus right / affect ($\underline{M}$ = 2.67; $\underline{SD}$ = 3.79) identification conditions. Refer to and Figure 10. In addition, Tukey's HSD post hoc comparison confirmed that the total correct for the left ear under the focus left condition ($\underline{M}$ = 14.10; $\underline{SD}$ = 4.15) was significantly greater than the total correct for the left ear under the focus right condition ($\underline{M}$ = 2.80; $\underline{SD}$ = 4.03). Refer to Figure 11. Likewise, Tukey's HSD post hoc comparison revealed that the total correct for the left ear for words ($\underline{M}$ = 7.73; $\underline{SD}$ = 6.37) was significantly less than the total correct for the left ear for affect ($\underline{M}$ = 9.13; $\underline{SD}$ = 7.61). Refer to Figure 12.

Similarly, there was a main effect of Focus, $F(1,24) = 70.37$, $\underline{p} = 0.0001$, using the REA scores. There was no interaction. Tukey's HSD post hoc comparison revealed that the total correct for the right ear under the focus right condition ($\underline{M}$ = 13.97; $\underline{SD}$ = 4.26) was significantly greater than under the

Figure 10. Total correct for the left ear as a function of focus and stimulus type.



FOCUS RIGHT
FOCUS LEFT
MEAN CORRECT (LEFT EAR)
20
18
16
14
12
10
8
6
4
2
WORD
AFFECT
STIMULUS TYPE

Figure 11. Total correct for the left ear as a function of focus.

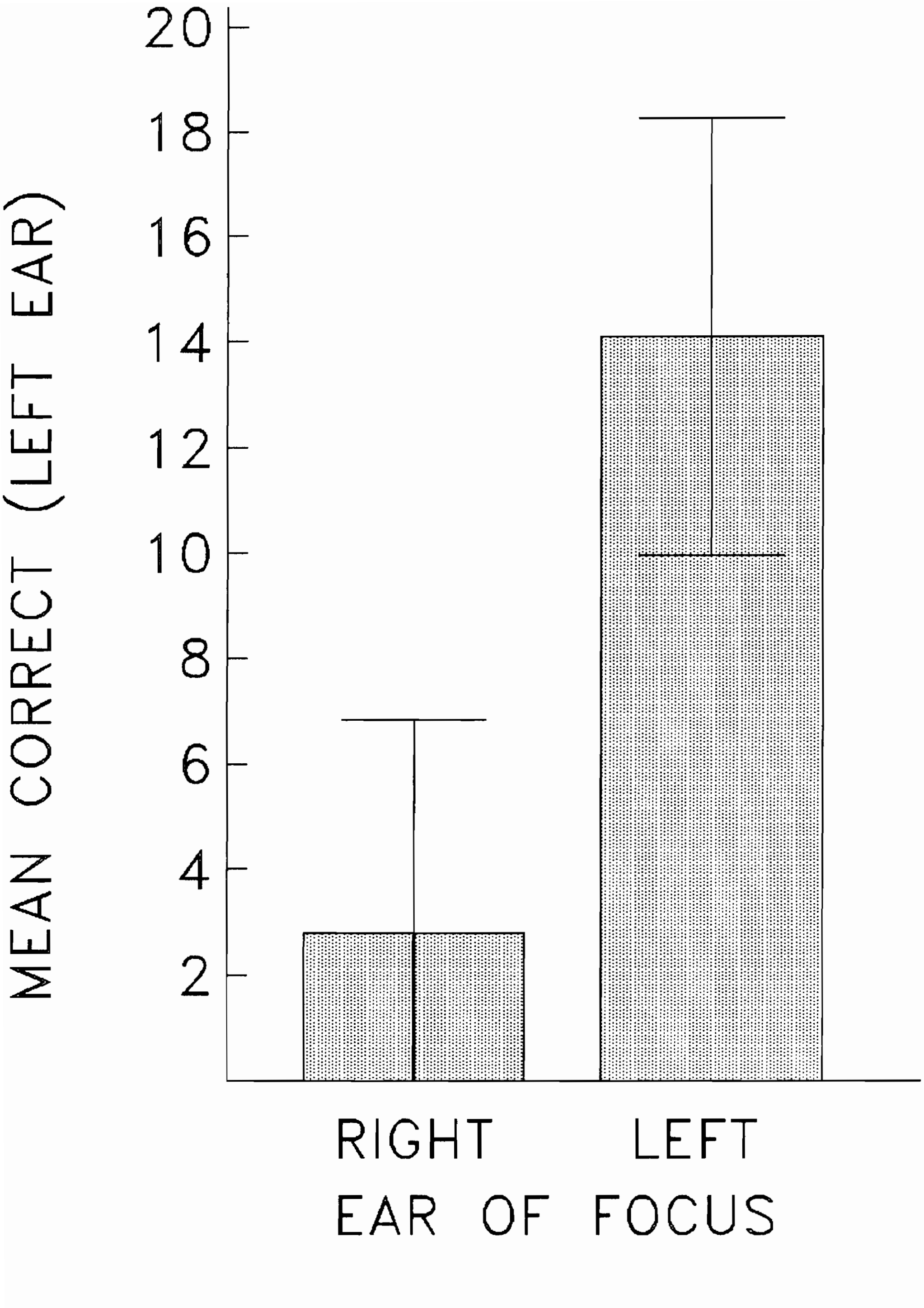
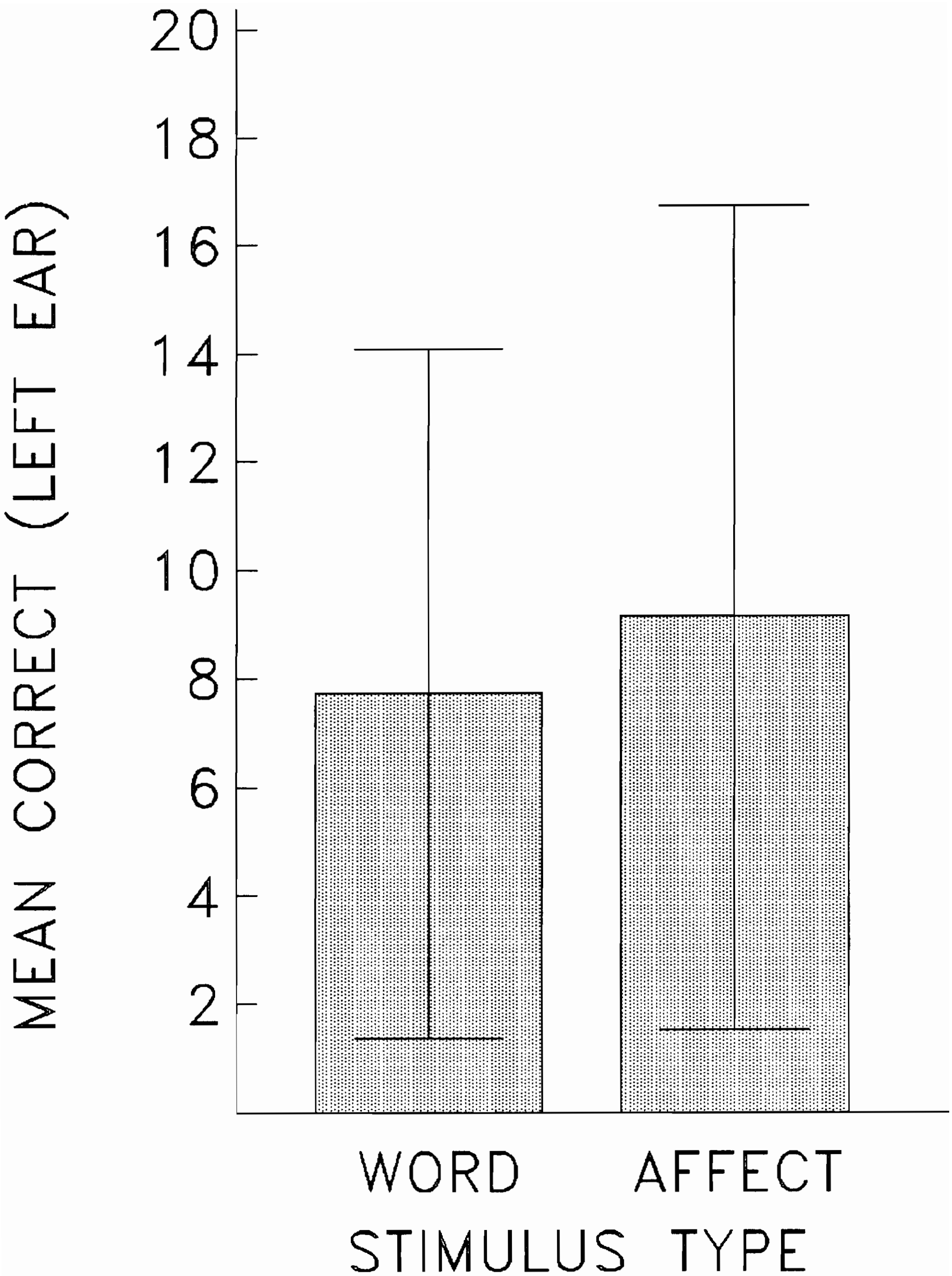

MEAN CORRECT (LEFT EAR)
20
18
16
14
12
10
8
6
4
2
RIGHT
LEFT
EAR OF FOCUS

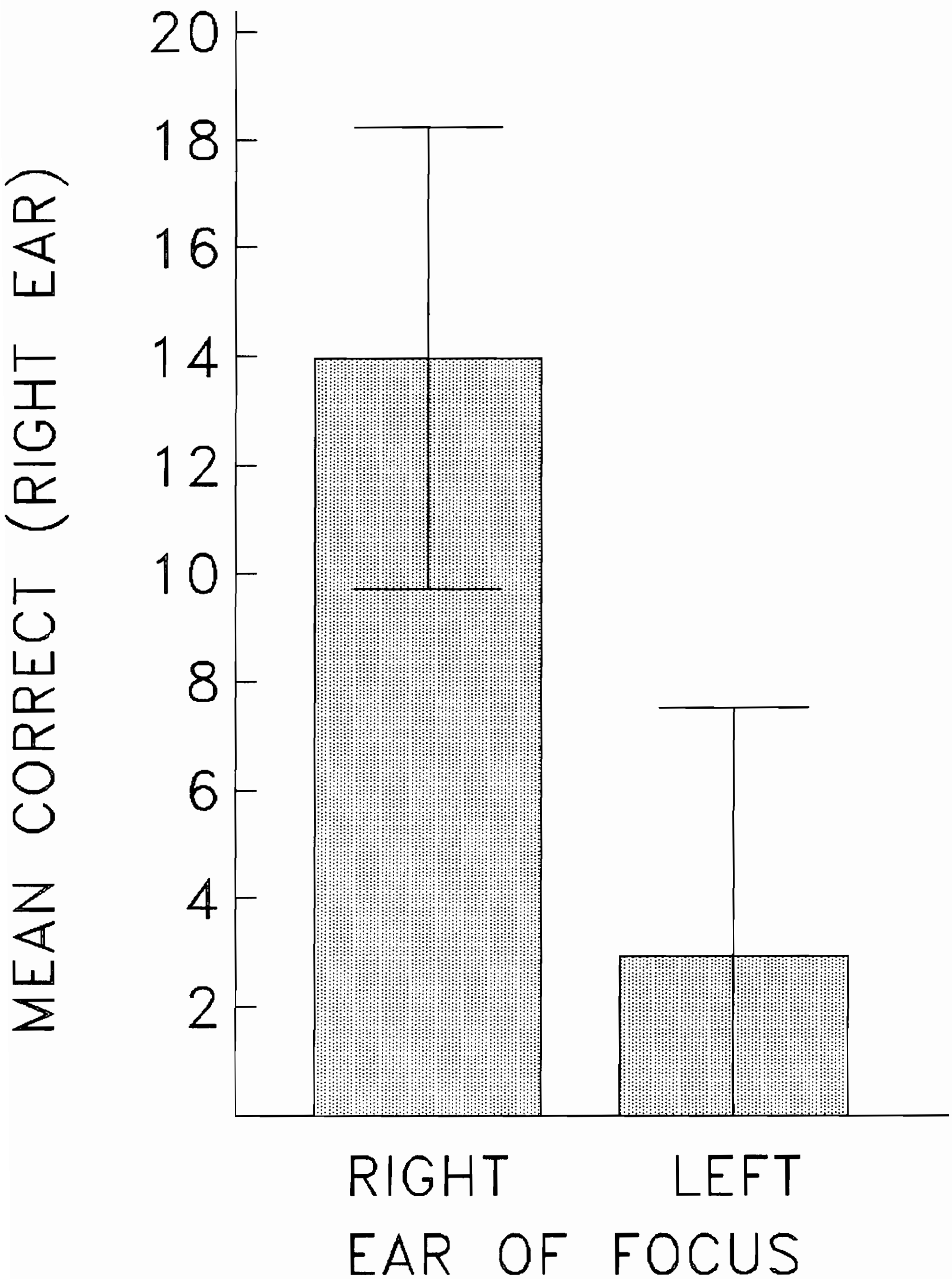
Figure 12. Total correct for the left ear as a function of stimulus type.


MEAN CORRECT (LEFT EAR)
20
18
16
14
12
10
8
6
4
2
WORD
AFFECT
STIMULUS TYPE

focus left condition (*M* = 2.93; *SD* = 4.59). Refer to Figure 13.

In conclusion, four addition types of analysis were performed with the data. First, ANOVA's were performed on the percentage of correct responses score (POC), which combines the REA and LEA totals (Repp, 1977). Refer to Appendix K for the results of this analysis. Second, an analysis was performed to compare positive (happy) and negative (mean totals for angry and sad) stimuli using half of Phase 1 data. Refer to Appendix L for the results of this analysis. Third, the analysis of Phase 2 data was rerun using all possible data. Refer to Appendix M for the results of this analysis. Fourth, analysis of all three hypotheses was rerun and ear of presentation was added as a factor. Refer to Appendix N for the results ofthis analysis.

Figure 13. Total correct for the right ear as a function of focus.


MEAN CORRECT (RIGHT EAR)
20
18
16
14
12
10
8
6
4
2
RIGHT
LEFT
EAR OF FOCUS

Discussion

This study was performed to assess differences in cerebral asymmetry as a function of fluency, stimulus type, and attentional focus. The most important findings of the present study were the main effect of fluency category and the interaction of fluency with affect. In addition, the main effects of stimulus (word or affect), affect (happy, sad, angry, or neutral), and focus replicate the findings of previous research (Bryden & MacCrae, 1989; Hagopian, et al., 1992; Tucker, 1981). Support for all three hypotheses was obtained.

Subjects higher in fluency exhibited greater total scores for stimuli presented to both the left and right ears than subjects lower in fluency. Refer to Figure 1, Figure 3, Figure 5, and Figure 7. In the first MANOVA, which used all Phase 1 data, subjects middle in fluency also exhibited higher total scores for stimuli presented to the right ear than subjects lower in fluency. Thus, we can infer that subjects higher in fluency achieve greater total dichotic listening scores for both propositional and nonpropositional speech than subjects lower in fluency.

This provides partial support for the first hypothesis, which proposed that subjects lower in fluency would exhibit less functional cerebral asymmetry for nonpropositional speech, and hence manifest less of an REA for words than subjects higher in fluency.

The finding that subjects higher in verbal fluency had greater LEA and REA scores for both propositional and nonpropostional speech partially supports the suggestion by Hunt, Lunneborg, and Lewis (1975) that subjects higher in verbal abilities utilize both cerebral systems more and show less patterns of lateralization in the perception of language, while subjects lower in verbal abilities use both cerebral systems less and show greater patterns of lateralization in the perception of language. Since the POC scores suggest that there is no significant difference in levels of fluency as a function of ear of presentation, it could be that subjects higher in fluency utilize both cerebral systems more than subjects lower in fluency.

Since all subjects were college students, the nature of the population tested could have led to the lack of an effect of fluency using the POC scores. The

FAS test was developed for use in clinical settings and many studies have suggested that lower fluency subjects have scores less than or equal to 20 and higher fluency subjects have scores greater than or equal to 30 (Borkowski, Benton, & Spreen, 1967). Since only three of the subjects tested in this study had a score less than or equal to 20, our study was made up of subjects higher in fluency relative to the clinical population.

In addition, fluency was found to interact with affect. Tucker (1981) proposed that the left cerebral system is more proficient with positive affective stimuli (happy). Annet and Kilshaw (1984) proposed the right-shift hypothesis, which implicated that subjects having language problems rely less on the left cerebral system for speech perception than subjects not having language problems. Thus, subjects having language problems might have increased difficulty with positive affective stimuli presented to the right ear than subjects not having language problems. This experiment provides some support for this, in that, subjects tending towards lower fluency scores (middle and lower fluency subjects) had lower total scores for stimuli presented to the right ear for happy stimuli than subjects with higher fluency scores (higher fluency subjects). Refer to Figure 9. This finding provides partial support for the second hypothesis, which stated that if there is reduced left asymmetry for nonpropositional speech in lower fluent subjects due to left cerebral impairment, subjects lower in fluency would exhibit less of an REA for happy affective stimuli and a heightened LEA for sad or angry affective stimuli.

As predicted by previous research (Bryden & MacCrae, 1989), total scores for stimuli presented to the left ear were greater for affect than for words (refer to Figure 2 and Figure 11), while total scores for stimuli presented to the right ear were greater for words than for affect (refer to Figure 4). Thus, we can infer that the left cerebral system is more proficient with nonpropositional speech, while the right cerebral system is more proficient with propositional speech.

Similarly, as predicted by previous research (Tucker, 1981), total scores for stimuli presented to the right ear were greater for positive affective stimuli (happy), while total scores for stimuli presented to the left ear were greater for negative affective stimuli (sad). For example, total scores for stimuli presented to the left ear were greater for sad than happy stimuli (refer to Figure 6). Conversely, total scores for stimuli presented to the right ear for neutral stimuli were greater than sad stimuli (refer to Figure 8). The finding that total scores for stimuli presented to either the left or right ear were greater for neutral than for happy stimuli would be anticipated if neutral is viewed as being an easier stimulus involving no prosody. Similarly, the finding that the total score for stimuli presented to the right ear for angry stimuli was greater than happy stimuli would be anticipated if the stimulus tape is taken into account. Some subjects reported after-the-fact that the angry tone of voice seemed to be louder and shorter (more staccato in enunciation) than the other tones of voice. The angry affective tone was found to be an average 3 db louder than the happy, sad, and neutral affective tones.

Finally, as predicted by previous research (Hagopian, et al., 1992), there was a main effect of focus or intention. Total scores for stimuli presented to the left ear were improved under the focus left condition. Conversely, total scores for stimuli presented to the right ear were superior under the focus right condition. This provides support for the third hypothesis, which proposed that identification of propositional and nonpropositional speech would vary as a function of focus or intention and the cerebral systems mediating these functions.

The nature of the experimental design and stimulus tape prevented one MANOVA from being performed. Whether subjects were asked to identify a word or affect in Block 1 or Block 2 was counterbalanced based on order of arrival. The hypotheses made in this study require that both stimulus (word or affect) and types of affective stimuli (happy, sad, angry, or neutral) be compared. To analyze the effect of word versus affect stimuli, as is needed for Hypothesis 1, all Phase 1 data (see Footnote 1) can be used. However, to analyze the effect of happy, sad, angry, and neutral types of affective stimuli, as is needed for Hypothesis 2, the data from only one of the blocks in Phase 1 can be used. This would be the total number correct for each of the affect conditions, while the subject was told to listen for a particular word. The same situation occurs in Phase 2 (see Footnote 2). Thus, for each hypothesis, a different subset of data and different MANOVA procedure was needed.

There are many possibilities for future research in the area of verbal fluency. For instance, it would be interesting to study interval estimation or time perception and verbal fluency. Numerous studies have suggested that cortical arousal or vigilance, defined as a readiness to detect and respond to environmental stimuli (Thompson & Spencer, 1966), plays a crucial role in performance. Under high arousal states induced by amphetamines, subjects significantly underestimate intervals and report that time is passing slowly (Luce, 1971). However, under lower arousal states induced by sedatives, subjects significantly overestimate intervals and report that time is passing quickly (Luce, 1971). If subjects lower in fluency rely less on the left cerebral system than subjects higher in fluency, they should show patterns of lower arousal and overestimate intervals between stimuli presented to the right ear.

In fact, Hunt, Lunneborg, and Lewis (1975) showed that subjects having better verbal abilities have faster reaction times for verbal stimuli. Thus, it could be that subjects lower in fluency have lower arousal patterns or reaction times for tests like the FAS than subjects higher in fluency.

It would also be interesting to study levels of illumination and verbal fluency. Previous researchers have suggested that higher levels of illumination are associated with higher levels of cortical arousal (Isaac, 1969). If this is the case, then low levels of illumination should lead to less arousal of the left cerebral system than higher levels of illumination. Conversely, if subjects lower in fluency rely less on the left cerebral system than subjects higher in fluency, they should show greater decrements in nonpropositional speech scores for the right ear under lower levels of illumination.

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Footnotes

[1]Phase 1, the nonfocused condition, was to include Block 1 through Block 4; however, when sixteen trials whereby the stimuli were identical in each ear was discovered in Block 3, the data for both Block 3 and Block 4 was discarded. Since Block 3 and Block 4 were identical to Block 1 and Block 2 and were designed as a built in replication test, the hypotheses could still be evaluated.

[2]Phase 2, the focused condition, included Block 5 and Block 6. Everything in Phase 2 is identical to Phase 1, except that whether the subject was told to focus right or left was counterbalanced based on order of arrival. Analysis of all factors but fluency in Phase 1 was within subjects. However, in Phase 2 the analysis included two between subjects factors, Fluency and Focus. Half of the subjects were told to either focus right or left, while a third of the subjects were either lower, middle, or higher in fluency. Because of these differences in the proportion of subjects in each category and the fact that fluency is a subject variable, the number of subjects in each of the fluency by stimulus groups was unequal. The number

of subjects in these groups ranged from five to eight. On a random basis, the data from subjects were discarded until all groups contained five subjects. Thus, including the three subjects initially dropped because of the selection criteria, 18 subjects were discarded in a random manner.

Appendix A

Informed Consent Form: Project Number 2067-93

TITLE OF EXPERIMENT:

The Neurobehavioral Correlates of Affect Perception

EXPERIMENT #: 2067-93

1. PURPOSE OF EXPERIMENT: You are invited to participate in a study about cerebral asymmetry for auditory perception.

2. PROCEDURE TO BE FOLLOWED IN THE STUDY: To accomplish the goals of the study, you will be asked to take a hearing acuity test for pure tones and listen to a tape of words. The experiment will take one and a half hours.

3: ANONYMITY OF SUBJECTS AND CONFIDENTIALITY OF THE RESULTS: The results of the study will be strictly confidential. At no time will the researchers release your results to anyone other than individuals working on the project without your written consent. The information you provide will have your name removed and only a subject number will identify you during the analysis and any write up of the research.

4: DISCOMFORTS AND RISKS FROM PARTICIPATING IN THE STUDY: There are no apparent risks to you for participation in this study.

5. POTENTIAL BENEFITS TO STUDENTS: In addition to identifying whether you potentially have a hearing problem, this study will help to provide information on cerebral asymmetry for auditory tasks.

6. FREEDOM TO WITHDRAW: You are free to withdraw from participation in this study at any time without penalty.

7. EXTRA CREDIT: For participation in this study you will receive two extra credit points.

8. USE OF THE RESEARCH DATA: The information from this research project may be used for scientific or educational purposes. It may be used at scientific meetings and/or published and republished in professional journals or books, or used for any other purpose which Virginia Tech's department of Psychology considers proper in the interest of education, knowledge, or research.

9. APPROVAL OF THE RESEARCH: This research has been approved by the Human Subjects Committee of the Department of Psychology and by the Institutional

Review Board of Virginia Tech.

10: SUBJECTS PERMISSION:

1. I have read and understand the above description of the study. I have had an opportunity to ask questions and have had them answered. I hereby acknowledge the above and give my consent for participation in this study.

2. I also understand that if I participate I may withdraw at any time without penalty.

3. I understand that should I have any questions about this research and its conduct, I should contact any of the following:

Primary Researcher: Katharine Snyder Phone: 232-4711

Faculty Advisor: Dr. David Harrison Phone: 231-4422

Chair, HSC: Dr. Robert J. Harvey Phone: 231-6581

Subject's Signature: ________________ Date: _________

Subject's Id # ____

Appendix B

The Dichotic Emotional Words Tape

Block 1, Block 3, and Block 5 (Left Ear - Right Ear)

1. NP-HT	19. HP-ST	37. AB-HT	55. HT-AD
2. NT-AP	20. ST-AD	38. ST-HP	56. HB-SP
3. HP-AD	21. NB-AT	39. ND-SB	57. AB-SP
4. AD-NB	22. NB-HD	40. AP-HT	58. NP-HB
5. SP-AD	23. AT-HP	41. HT-ND	59. AT-SD
6. AD-NP	24. ST-ND	42. AD-SB	60. ND-SP
7. SD-HP	25. HB-AT	43. SP-HT	61. HP-ND
8. AD-HB	26. AP-ST	44. NB-AP	62. SD-AP
9. SB-AT	27. SB-NT	45. HD-AP	63. NB-SP
10. HT-SB	28. SB-HP	46. HP-NB	64. HD-SB
11. NP-AB	29. NT-SB	47. SD-HT	65. NT-HD
12. SD-NB	30. HD-SP	48. SP-AT	66. NP-SD
13. SD-NT	31. AP-ND	49. HB-ND	67. AB-ST
14. AD-NT	32. HD-NP	50. AP-HB	68. AT-NP
15. HP-AB	33. HB-SD	51. AB-HD	69. ST-HD
16. HP-NT	34. NB-ST	52. ND-AT	70. NT-HB
17. NT-AB	35. SB-AP	53. SP-NT	71. ND-AB
18. ST-HB	36. HT-NB	54. AT-HD	72. AB-SD

Block 2, Block 4, and Block 6 (Left Ear - Right Ear)

1. HT-SP	19. HP-SB	37. HT-AP	55. SB-ND
2. HP-SD	20. HB-NT	38. SP-ND	56. ST-AP
3. AB-NP	21. AT-HB	39. NB-HT	57. HB-NP
4. NB-HP	22. NT-AD	40. AP-SB	58. AP-NT
5. NP-HD	23. NP-SB	41. SD-NP	59. SB-HD
6. AD-HT	24. NT-HP	42. AP-SD	60. NT-SP
7. AT-SB	25. HT-AB	43. HD-NB	61. AD-HP
8. NP-ST	26. ST-NB	44. NT-SD	62. AT-NB
9. ND-AP	27. HP-AT	45. AP-HD	63. SP-HD
10. HD-ST	28. AB-NT	46. NB-SD	64. SB-AD
11. NB-AD	29. HB-ST	47. SP-AB	65. ND-HB
12. ST-HP	30. ND-HT	48. SB-NT	66. SD-AT
13. HB-AP	31. HT-SD	49. NP-AD	67. ND-ST
14. AT-ND	32. HT-NP	50. SP-NB	68. AT-SP
15. SD-HB	33. SD-AB	51. ST-AB	69. AB-ND
16. AB-HP	34. NP-AT	52. ND-HP	70. HD-AB
17. HB-AD	35. HD-NT	53. HD-AT	71. SB-HT
18. AP-NB	36. AD-SP	54. AD-ST	72. SP-HB

H = Happy	S = Sad	A = Angry	N = Neutral
B = Bower	D = Dower	P = Power	T = Tower

Appendix C

Audiometric Case History Form

NAME____AGE__________

EXPERIMENTER____

	Frequency						
	500	750	1000	1000	1500	2000	3000
HTL in Decibels	___	___	____	____	____	____	____

1) Which hand do you write with?

2) Have you ever had any hearing problems like ear infections, tubes in the ears, or worn a hearing aide?

3) Have you ever had a head injury or been hospitalized?

Appendix D

Stimulus word and affective tone combinations

Number	Word	Affective Tone
1.	Power	Happy
2.	Power	Sad
3.	Power	Angry
4.	Power	Neutral
5.	Bower	Happy
6.	Bower	Sad
7.	Bower	Angry
8.	Bower	Neutral
9.	Tower	Happy
10.	Tower	Sad
11.	Tower	Angry
12.	Tower	Neutral
13.	Dower	Happy
14.	Dower	Sad
15.	Dower	Angry
16.	Dower	Neutral

Appendix E

Phase 1 Raw Data Used to Evaluate Hypothesis 1

Fluency Group	Subject Number	Stimulus	LEA	REA
1	7	1	7	14
1	7	2	17	9
1	14	1	12	17
1	14	2	15	13
1	16	1	17	18
1	16	2	16	10
1	19	1	10	7
1	19	2	17	18
1	20	1	5	13
1	20	2	11	11
1	21	1	14	2
1	21	2	5	12
1	24	1	13	16
1	24	2	16	10

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix E Continued

<u>Phase 1 Raw Data Used to Evaluate Hypothesis 1</u>

Fluency Group	Subject Number	Stimulus	LEA	REA
1	30	1	18	18
1	30	2	13	8
1	31	1	7	8
1	31	2	10	6
1	32	1	3	15
1	32	2	14	12
1	33	1	9	8
1	33	2	7	7
1	34	1	4	6
1	34	2	16	15
1	38	1	5	14
1	38	2	14	5
1	39	1	9	11
1	39	2	12	7
1	41	1	13	18

<u>Note</u>. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix E Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 1

Fluency Group	Subject Number	Stimulus	LEA	REA
1	41	2	16	9
2	1	1	10	11
2	1	2	15	3
2	4	1	15	15
2	4	2	12	13
2	5	1	15	14
2	5	2	15	17
2	6	1	1	17
2	6	2	15	18
2	8	1	12	13
2	8	2	13	9
2	11	1	12	18
2	11	2	14	13
2	15	1	15	12
2	15	2	12	11

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix E Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 1

Fluency Group	Subject Number	Stimulus	LEA	REA
2	22	1	11	18
2	22	2	16	13
2	23	1	7	14
2	23	2	18	15
2	25	1	13	16
2	25	2	15	15
2	27	1	14	17
2	27	2	18	17
2	37	1	11	13
2	37	2	17	11
2	40	1	9	13
2	40	2	8	4
2	43	1	13	18
2	43	2	18	18
2	48	1	15	14

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix E Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 1

Fluency Group	Subject Number	Stimulus	LEA	REA
2	48	2	18	18
3	2	1	8	18
3	2	2	17	13
3	3	1	15	16
3	3	2	10	8
3	9	1	12	17
3	9	2	10	7
3	10	1	14	18
3	10	2	13	18
3	12	1	17	16
3	12	2	13	12
3	17	1	14	16
3	17	2	16	17
3	18	1	13	14
3	18	2	16	17

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix E Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 1

Fluency Group	Subject Number	Stimulus	LEA	REA
3	26	1	17	18
3	26	2	17	8
3	28	1	11	15
3	28	2	10	15
3	29	1	16	18
3	29	2	18	15
3	35	1	9	9
3	35	2	18	16
3	36	1	13	13
3	36	2	18	17
3	42	1	18	17
3	42	2	16	12
3	46	1	12	15
3	46	2	17	18
3	47	1	8	18

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix E Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 1

Fluency Group	Subject Number	Stimulus	LEA	REA
3	47	2	14	15

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix F

Tables for the Analysis of Hypothesis 1

Table 1

Analysis of Variance Procedure for the LEA Scores

Source	DF	Sum of Squares	F	PR > F
G	2	98.42	3.86	0.0288
STM	1	187.78	14.63	0.0004
G*STM	2	15.09	0.59	0.5601
S(G)	42	534.87		
STM*S(G)	42	539.13		

Note. Factors are defined as follows: VF Group (G), Stimulus Type (STM), and subjects (S). The VF groups are lower, middle, and higher fluency. The stimulus types are word or affect. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 2

Descriptive Statistics for the Main Effect of Group using LEA Scores

Descriptive Statistic	Lower Fluency	Middle Fluency	Higher Fluency
Mean Total	11.50	13.23	14.00
Standard Deviation	4.49	3.00	3.17
Maximum Score	36.00	36.00	36.00
Number of Subjects	15.00	15.00	15.00

Note. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 3

Descriptive Statistics for the Main Effect of Stimulus Type using LEA Scores

Descriptive Statistic	Word	Affect
Mean Total	11.47	14.36
Standard Deviation	4.09	3.21
Maximum Score	18.00	18.00
Number of Observations	45.00	45.00

Note. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 4

<u>Analysis of Variance Procedure for the REA Scores</u>

Source	DF	Sum of Squares	F	PR > F
G	2	213.62	7.59	0.0015
STM	1	92.01	6.26	0.0163
G*STM	2	0.42	0.01	0.9857
S(G)	42	591.20		
STM*S(G)	42	617.07		

<u>Note</u>. Factors are defined as follows: VF Group (G), Stimulus (STM), and subjects (S). The VF groups are lower, middle, and higher fluency. The stimulus types are word or affect. The REA scores represent the total correct for stimuli presented to the right ear.

Table 5

Descriptive Statistics for the Main Effect of Group using REA Scores

Descriptive Statistic	Lower Fluency	Middle Fluency	Higher Fluency
Mean Total	11.23	13.93	14.87
Standard Deviation	4.42	3.81	3.28
Maximum Score	36.00	36.00	36.00
Number of Subjects	15.00	15.00	15.00

Note. The REA scores represent the total correct for stimuli presented to the right ear.

Table 6

Descriptive Statistics for the Main Effect of Stimulus Type using REA Scores

Descriptive Statistic	Word	Affect
Mean Total	14.36	12.33
Standard Deviation	3.75	4.27
Maximum Score	18.00	18.00
Number of Observations	45.00	45.00

Note. The REA scores represent the total correct for stimuli presented to the right ear.

Appendix G

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
1	7	1	1	4
1	7	2	4	4
1	7	3	0	3
1	7	4	2	3
1	14	1	1	3
1	14	2	3	5
1	14	3	4	5
1	14	4	4	4
1	16	1	5	4
1	16	2	4	5
1	16	3	2	5
1	16	4	5	4
1	19	1	1	2
1	19	2	3	0

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
1	19	3	2	2
1	19	4	4	3
1	20	1	1	4
1	20	2	2	3
1	20	3	2	3
1	20	4	0	3
1	21	1	3	0
1	21	2	5	1
1	21	3	3	1
1	21	4	3	0
1	24	1	4	4
1	24	2	0	3
1	24	3	4	4
1	24	4	4	5
1	30	1	1	4

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
1	30	2	2	5
1	30	3	2	5
1	30	4	3	4
1	31	1	1	1
1	31	2	2	2
1	31	3	0	2
1	31	4	4	3
1	32	1	0	3
1	32	2	2	4
1	32	3	0	4
1	32	4	1	4
1	33	1	2	3
1	33	2	3	0
1	33	3	3	1
1	33	4	1	4

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
1	34	1	1	2
1	34	2	1	0
1	34	3	1	0
1	34	4	1	4
1	38	1	0	3
1	38	2	3	4
1	38	3	1	4
1	38	4	1	3
1	39	1	0	0
1	39	2	2	2
1	39	3	3	5
1	39	4	4	4
1	41	1	5	4
1	41	2	1	5
1	41	3	3	4

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
1	41	4	4	5
2	1	1	3	2
2	1	2	1	3
2	1	3	2	2
2	1	4	4	4
2	4	1	1	3
2	4	2	5	4
2	4	3	4	4
2	4	4	5	4
2	5	1	1	2
2	5	2	4	4
2	5	3	5	4
2	5	4	5	4
2	6	1	0	4
2	6	2	0	3

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
2	6	3	0	5
2	6	4	1	5
2	8	1	1	1
2	8	2	4	3
2	8	3	4	5
2	8	4	3	4
2	11	1	2	4
2	11	2	2	5
2	11	3	4	4
2	11	4	4	5
2	15	1	3	2
2	15	2	3	3
2	15	3	1	3
2	15	4	5	3
2	22	1	2	4

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
2	22	2	4	4
2	22	3	2	5
2	22	4	3	5
2	23	1	1	1
2	23	2	4	4
2	23	3	1	4
2	23	4	1	5
2	25	1	2	2
2	25	2	5	4
2	25	3	4	5
2	25	4	2	5
2	27	1	4	4
2	27	2	4	4
2	27	3	3	4
2	27	4	3	5

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
2	37	1	0	0
2	37	2	5	4
2	37	3	3	4
2	37	4	3	5
2	40	1	1	1
2	40	2	3	4
2	40	3	3	4
2	40	4	2	4
2	43	1	3	4
2	43	2	4	5
2	43	3	3	4
2	43	4	3	5
2	48	1	5	2
2	48	2	3	4
2	48	3	2	4

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
2	48	4	5	4
3	2	1	1	6
3	2	2	1	4
3	2	3	4	4
3	2	4	2	4
3	3	1	5	5
3	3	2	1	1
3	3	3	4	4
3	3	4	5	5
3	9	1	2	3
3	9	2	3	5
3	9	3	3	4
3	9	4	4	5
3	10	1	4	4
3	10	2	3	5

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
3	10	3	3	4
3	10	4	4	5
3	12	1	4	3
3	12	2	4	5
3	12	3	5	4
3	12	4	4	4
3	17	1	2	6
3	17	2	4	4
3	17	3	5	3
3	17	4	5	4
3	18	1	1	4
3	18	2	4	4
3	18	3	3	3
3	18	4	5	3

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
3	26	1	5	4
3	26	2	3	5
3	26	3	5	4
3	26	4	4	5
3	28	1	2	3
3	28	2	3	3
3	28	3	2	4
3	28	4	4	5
3	29	1	4	4
3	29	2	4	5
3	29	3	4	5
3	29	4	4	4
3	35	1	0	2
3	35	2	2	0
3	35	3	4	3

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
3	35	4	3	4
3	36	1	0	2
3	36	2	4	4
3	36	3	4	3
3	36	4	5	4
3	42	1	5	5
3	42	2	4	4
3	42	3	5	4
3	42	4	4	4
3	46	1	2	2
3	46	2	3	4
3	46	3	2	5
3	46	4	5	4
3	47	1	3	5
3	47	2	1	5

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix G Continued

Phase 1 Raw Data Used to Evaluate Hypothesis 2

Fluency Group	Subject Number	Affect	LEA	REA
3	47	3	1	4
3	47	4	3	4

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Affect 1 is happy, Affect 2 is sad, Affect 3 is angry, and Affect 4 is neutral. The LEA and REA scores are the total correct for each ear for each type of affect and have a maximum value of 8.

Appendix H

Tables for the Analysis of Hypothesis 2

Table 1

Analysis of Variance Procedure for the LEA Scores

Source	DF	Sum of Squares	F	PR > F
G	2	35.34	5.41	0.0081
A	3	36.06	7.75	0.0001
G*A	6	11.19	1.20	0.3097
S(G)	42	137.30		
A*S(G)	126	195.50		

Note. The factors are defined as follows: VF group (G), types of affect (A), and subjects (S). The VF groups are lower, middle, and higher fluency. The affects are happy, sad, angry, and neutral. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 2

Descriptive Statistics for the Main Effect of Group using LEA Scores

Descriptive Statistic	Lower Fluency	Middle Fluency	Higher Fluency
Mean Total	2.23	2.83	3.32
Standard Deviation	1.51	1.30	1.38
Maximum Score	18.00	18.00	18.00
Number of Subjects	15.00	15.00	15.00

Note. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 3

Descriptive Statistics for the Main Effect of Affect using LEA Scores

Descriptive Statistic	Happy	Angry	Sad	Neutral
Mean Total	2.11	2.78	2.93	3.36
Standard Deviation	1.65	1.50	1.34	1.40
Maximum Score	9.00	9.00	9.00	9.00
Number of Observations	45.00	45.00	45.00	45.00

Note. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 4

Analysis of Variance Procedure for the REA Scores

Source	DF	Sum of Squares	F	PR > F
G	2	24.63	3.91	0.0278
A	3	27.66	9.64	0.0001
G*A	6	16.52	2.88	0.0116
S(G)	42	132.37		
A*S(G)	126	120.57		

Note. The factors are defined as follows: VF group (G), types of affect (A), and subjects (S). The VF groups are lower, middle, and higher fluency. The affects are happy, sad, angry, and neutral. The REA scores represent the total correct for stimuli presented to the right ear.

Table 5

Descriptive Statistics for the Main Effect of Group using REA Scores

Descriptive Statistic	Lower Fluency	Middle Fluency	Higher Fluency
Mean Total	3.08	3.70	3.97
Standard Deviation	1.57	1.20	1.09
Maximum Score	18.00	18.00	18.00
Number of Subjects	15.00	15.00	15.00

Note. The REA scores represent the total correct for stimuli presented to the right ear.

Table 6

Descriptive Statistics for the Main Effect of Affect using REA Scores

Descriptive Statistic	Happy	Sad	Angry	Neutral
Mean Total	3.00	3.53	3.71	4.09
Standard Deviation	1.49	1.50	1.16	0.92
Maximum Score	9.00	9.00	9.00	9.00
Number of Observations	45.00	45.00	45.00	45.00

Note. The REA scores represent the total correct for stimuli presented to the Right ear.

Table 7

Descriptive Statistics for the Group by Affect Interaction using REA Scores

Descriptive Statistic	Lower Happy	Middle Happy	Higher Happy	Lower Neutral	Middle Neutral	Higher Neutral
M	2.73	2.40	3.87	3.53	4.47	4.27
SD	1.48	1.35	1.38	0.55	0.64	0.59
Maximum Score	9.00	9.00	9.00	9.00	9.00	9.00
n	15.00	15.00	15.00	15.00	15.00	15.00

Note. The descriptive statistics are defined as follows: Mean Total (*M*), standard deviation (*SD*), and number of observations (n). Lower and higher refer to verbal fluency categories. The REA scores represent the total correct for stimuli presented to the right ear.

Appendix I

Phase 2 Raw Data Used to Evaluate Hypothesis 3

Fluency Group	Subject Number	Stimulus	Focus	LEA	REA
1	14	1	2	1	18
1	14	2	2	0	17
1	16	1	3	1	18
1	16	2	3	3	10
1	19	1	3	13	3
1	19	2	3	18	0
1	21	1	2	14	1
1	21	2	2	4	10
1	32	1	2	0	18
1	32	2	2	3	14
1	33	1	3	10	3
1	33	2	3	18	15
1	34	1	2	0	14
1	34	2	2	0	17

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. Focus 2 is the focus right condition and Focus 3 is the focus left condition. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix I Continued

Phase 2 Raw Data Used to Evaluate Hypothesis 3

Fluency Group	Subject Number	Stimulus	Focus	LEA	REA
1	38	1	2	0	15
1	38	2	2	0	7
1	39	1	3	11	0
1	39	2	3	16	1
1	41	1	3	14	10
1	41	2	3	18	0
2	6	1	2	10	8
2	6	2	2	12	8
2	8	1	2	1	15
2	8	2	2	10	14
2	11	1	3	13	2
2	11	2	3	18	0
2	15	1	3	15	0
2	15	2	3	14	0
2	22	1	3	17	3

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. Focus 2 is the focus right condition and Focus 3 is the focus left condition. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix I Continued

Phase 2 Raw Data Used to Evaluate Hypothesis 3

Fluency Group	Subject Number	Stimulus	Focus	LEA	REA
2	22	2	3	18	0
2	23	1	2	0	14
2	23	2	2	0	13
2	37	1	3	11	0
2	37	2	3	18	0
2	40	1	2	0	12
2	40	2	2	1	14
2	43	1	3	13	3
2	43	2	3	18	0
2	48	1	2	3	18
2	48	2	2	0	18
3	9	1	3	13	6
3	9	2	3	13	1
3	10	1	2	0	18
3	10	2	2	0	17

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. Focus 2 is the focus right condition and Focus 3 is the focus left condition. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix I Continued

Phase 2 Raw Data Used to Evaluate Hypothesis 3

Fluency Group	Subject Number	Stimulus	Focus	LEA	REA
3	12	1	2	5	16
3	12	2	2	5	6
3	17	1	3	16	0
3	17	2	3	13	0
3	26	1	2	8	16
3	26	2	2	3	14
3	29	1	3	17	0
3	29	2	3	18	2
3	35	1	3	12	5
3	35	2	3	17	1
3	36	1	2	1	15
3	36	2	2	2	17
3	46	1	2	1	17
3	46	2	2	0	18
3	47	1	3	13	3

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. Focus 2 is the focus right condition and Focus 3 is the focus left condition. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix I Continued

Phase 2 Raw Data Used to Evaluate Hypothesis 3

Fluency Group	Subject Number	Stimulus	Focus	LEA	REA
3	47	2	3	14	2

Note. Group 1 is lower fluency (FAS less than 32), Group 2 is middle fluency (FAS between 32 and 41), and Group 3 is higher fluency (FAS greater than 41). Stimulus 1 is a word and Stimulus 2 is an affect. Focus 2 is the focus right condition and Focus 3 is the focus left condition. The LEA and REA scores are the total correct for each ear for each stimulus and have a maximum value of 24.

Appendix J

Tables for the Analysis of Hypothesis 3

Table 1

Analysis of Variance Procedure for the LEA Scores

Source	DF	Sum of Squares	F	PR > F
G	2	60.43	1.11	0.3446
FOCUS	1	1926.67	71.03	0.0001
STM	1	29.40	4.79	0.0386
G*FOCUS	2	11.63	0.21	0.8085
G*STM	2	18.90	1.54	0.2351
FOCUS*STM	1	38.40	6.25	0.0196
G*FOCUS*STM	2	16.90	1.38	0.2718
S(G*FOCUS)	24	651.00		
STM*S(G*FOCUS)	24	147.40		

Note. Factors are defined as follows: VF group (G), intention (FOCUS), stimulus (STM), and subjects (S). VF groups are lower, middle, and higher fluency. Focus conditions are focus right or focus left. Stimulus types are word or affect. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 2

Descriptive Statistics for the Main Effect of Focus using LEA Scores

Descriptive Statistic	Focus Right	Focus Left
Mean Total	2.80	14.10
Standard Deviation	1.03	4.15
Maximum Score	36.00	36.00
Number of Subjects	15.00	15.00

Note. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 3

Descriptive Statistics for the Main Effect of Stimulus Type using LEA Scores

Descriptive Statistic	Word	Affect
Mean Total	7.73	9.13
Standard Deviation	6.37	7.61
Maximum Score	18.00	18.00
Number of Observations	30.00	30.00

Note. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 4

Descriptive Statistics for the Focus by Stimulus Type Interaction using LEA Scores

Descriptive Statistic	Focus Right Word	Focus Right Affect	Focus Left Word	Focus Left Affect
Mean Total	2.87	2.67	12.60	15.60
Standard Deviation	1.38	1.79	3.83	4.01
Maximum Score	18.00	18.00	18.00	18.00
Number of Observations	15.00	15.00	15.00	15.00

Note. The LEA scores represent the total correct for stimuli presented to the left ear.

Table 5

Analysis of Variance Procedure for the REA Scores

Source	DF	Sum of Squares	F	PR > F
G	2	61.90	1.19	0.3208
FOCUS	1	1826.02	70.37	0.0001
STM	1	20.42	1.60	0.2187
G*FOCUS	2	117.63	2.27	0.1254
G*STM	2	3.03	0.12	0.8888
FOCUS*STM	1	2.82	0.22	0.6432
G*FOCUS*STM	2	3.03	0.12	0.8888
S(G*FOCUS)	24	622.80		
STM*S(G*FOCUS)	24	307.20		

Note. The factors are defined as follows: VF group (G), intention (FOCUS), stimulus (STM), and subjects (S). VF groups are lower, middle, and higher fluency. Focus conditions are focus right or focus left. Stimulus types are word or affect. The REA scores represent the total correct for stimuli presented to the right ear.

Table 6

Descriptive Statistics for the Main Effect of Focus using REA Scores

Descriptive Statistic	Focus Left	Focus Right
Mean Total	2.93	13.97
Standard Deviation	4.59	4.26
Maximum Score	36.00	36.00
Number of Subjects	15.00	15.00

Note. The REA scores represent the total correct for stimuli presented to the right ear.

Appendix K

The Percentage of Correct Responses Score

In a dual response situation, different stimuli are presented to each ear and the subject is asked to identify these stimuli. The present study assesses total correct for each ear separately; however, previous research has suggested methods of combining the two scores so that the magnitude of ear asymmetry can be determined on a continuous scale (Repp, 1977).

One of the most common procedures for doing this is to take the difference between the proportions correct in each ear (Repp, 1977); however, the problem with difference scores is that they impose an upper limit. Two methods of analysis have been proposed to circumvent this imposed upper limit (Repp, 1977). These are the Percentage of Correct responses score (POC) and the Percentage of Errors score (POE) (Harshman & Krashen, 1972; see Repp, 1977).

To derive the POC and POE scores, the proportion correct for stimuli presented to the right ear (pR) and the proportion correct for stimuli presented to the left ear (pL) are first calculated. The following formula is used to calculate the POC score:

$$POC = (pR-pL) / (pR+pL)$$

The following formula is used to calculate the POE score:

$$POE = (pR-pL) / (2-pR-pL)$$

The range of the POC and POE scores is between -1 (perfect left ear bias) to +1 (perfect right ear bias). Since the dependent variables used in this study were the total number correct for the left (LEA) and right (REA) ear, the POC score was chosen for an additional measure rather than the POE score.

A two-way mixed factorial ANOVA with the between subjects factor of Fluency (higher, middle, and lower) and the repeated measures factor of Stimulus Type (word and affect) was performed using the POC scores derived from the Hypothesis 1 data set (refer to Appendix F). A main effect of Stimulus Type, $F(1,42) = 19.66$, $\underline{p} = .0001$, was found. There was no interaction. Tukey's HSD post hoc comparison revealed that the POC scores for affect (*M* = -0.16; *SD* = 0.28) showed a significant left ear bias, while the POC scores for words (*M* = 0.0938; *SD* = 0.18) showed a slight right ear bias. Refer to Table 1 for the ANOVA summary and Table 2, Table 3, and Table 4 for the descriptive statistics of this analysis.

These results are consistent with previous findings for Hypothesis 1. The direction of significance changed for the main effect of Stimulus Type, in that, LEA scores for affect were greater than words (refer to Figure 2) and REA scores were greater for words than for affect (refer to Figure 4). Thus, scores seem to vary for Stimulus Type with ear of presentation and the main effect of Stimulus Type using the POC scores is not surprising.

A two-way mixed factorial ANOVA with the between subjects factor of Fluency (higher, middle, and lower) and the repeated measures factor of Affect (happy, sad, angry, and neutral) was performed using the POC scores from the Hypothesis 2 data set (refer to Appendix H). No significant effects were found. Refer to Table 5 for the ANOVA summary and Table 6 and Table 7 for the descriptive statistics of this analysis.

Table 1

Analysis of Variance Procedure for Hypothesis 1 Using the POC Scores

Source	DF	Sum of Squares	F	PR > F
G	2	0.0003	0.00	0.9965
STM	1	1.4104	19.66	0.0001
G*STM	2	0.1458	1.02	0.3706
S(G)	42	1.7005		
STM*S(G)	42	3.0124		

Note. The factors are defined as follows: VF group (G), Stimulus Type (STM) and subjects (S). The VF groups are lower, middle, and higher fluency. The stimulus types are word or affect.

Table 2

Descriptive Statistics for the Factor of Group in Hypothesis 1

Descriptive Statistic	Lower Fluency	Middle Fluency	Higher Fluency
Mean POC	-0.0400	-0.0324	0.2571
Standard Deviation	0.3559	0.2571	0.0153
Number of Subjects	15.0000	15.0000	15.0000

Table 3

Descriptive Statistics for the Main Effect of Stimulus Type in Hypothesis 1

Descriptive Statistic	Word	Affect
Mean POC	0.0938	-0.1600
Standard Deviation	0.1800	0.2831
Number of Observations	45.0000	45.0000

Table 4

Descriptive Statistics for the Group x Stimulus Type Factor in Hypothesis 1

Descriptive Statistic	Lower Word	Lower Affect	Middle Word	Middle Affect	Higher Word	Higher Affect
Mean POC	0.20	-0.14	0.16	-0.10	0.10	-0.04
Standard Deviation	0.39	0.21	0.28	0.22	0.11	0.16
Number of Observations	15.00	15.00	15.00	15.00	15.00	15.00

Table 5

Analysis of Variance Procedure for Hypothesis 2 Using the POC Scores

Source	DF	Sum of Squares	F	PR > F
G	2	0.1756	0.26	0.7691
A	3	0.3122	0.69	0.5584
G*A	6	0.6197	0.68	0.6646
S(G)	42	13.9624		
A*S(G)	126	18.9421		

Note. The factors are defined as follows: VF group (G), Affect (A) and subjects (S). The VF groups are lower, middle, and higher fluency. The affect types are happy, sad, angry, and neutral.

Table 6

<u>Descriptive Statistics for the Factor of Group in Hypothesis 2</u>

Descriptive Statistic	Lower Fluency	Middle Fluency	Higher Fluency
Mean POC	0.1908	0.1757	0.1183
Standard Deviation	0.6237	0.2932	0.3185
Number of Subjects	15.0000	15.0000	15.0000

Table 7

Descriptive Statistics for the Factor of Affect in Hypothesis 2

Descriptive Statistic	Happy	Sad	Angry	Neutral
Mean POC	-0.2235	-0.1114	-0.1718	-0.1396
Standard Deviation	0.3514	0.3437	0.3533	0.3170
Number of Observations	45.0000	45.0000	45.0000	45.0000

These results are consistent with the previous findings for Hypothesis 2. The direction of significance was the same for all of the main effects found. Higher fluency subjects had greater LEA and REA scores than lower fluency subjects (refer to Figure 5 and Figure 7). The REA and LEA scores for neutral were greater than sad and the REA and LEA scores for sad were greater than happy (refer to Figure 6 and Figure 8). Thus, scores do not seem to vary for Fluency or Affect with ear of Presentation and it is not anticipated that there would be a main effect of Fluency or Affect using the POC scores.

A three-way mixed factorial ANOVA with the between subjects factors of Fluency (higher, middle, and lower) and Focus (focus left or focus right) and the repeated measures factor of Stimulus Type (word or affect) was performed using the POC scores from the Hypothesis 3 data set (refer to Appendix J). A main effect of Focus, $F(1,24) = 128.92$, $p = .0001$, was found. No interactions were found. Tukey's HSD post hoc comparison revealed that the POC scores under the focus right condition ($M = 0.75$; $SD = 0.35$) showed a significant right ear bias, while the POC scores under the focus left condition (*M* = -0.71; *SD* = 0.45) showed a significant left ear bias. Refer to Table 8 for the ANOVA summary and Table 9, Table 10, Table 11, and Table 12 for the descriptive statistics on this analysis.

These results are consistent with previous findings for Hypothesis 3. The direction of significance changed for the main effect of Focus, in that, LEA scores were greater for focus left than for focus right (refer to Figure 10) and REA scores were greater for focus right than for focus left (refer to Figure 13). Thus, scores do seem to vary for focus with ear of presentation and the main effect of focus using the POC scores is not surprising.

Table 8

Analysis of Variance Procedure for Hypothesis 3

Using the POC Scores

Source	DF	Sum of Squares	F	PR > F
G	2	0.3387	0.69	0.5133
FOCUS	1	31.8388	128.92	0.0001
STM	1	0.0557	0.51	0.4826
G*FOCUS	2	0.2136	0.43	0.6539
G*STM	2	0.7464	3.42	0.0562
FOCUS*STM	1	0.0287	0.26	0.6130
G*FOCUS*STM	2	0.0000	0.00	1.0000
S(G*FOCUS)	24	5.9271		
STM*S(G*FOCUS)	23	2.5125		

Note. The factors are defined as follows: VF group (G), Affect (A) and subjects (S). The VF groups are lower, middle, and higher fluency. The affect types are happy, sad, angry, and neutral.

Table 9

Descriptive Statistics for the Factor of Group in Hypothesis 3

Descriptive Statistic	Lower Fluency	Middle Fluency	Higher Fluency
Mean POC	-0.0715	0.1123	0.0276
Standard Deviation	0.8550	0.8790	0.8080
Number of Subjects	10.0000	10.0000	10.0000

Table 10

Descriptive Statistics for the Main Effect of Focus in Hypothesis 3

Descriptive Statistic	Focus Left	Focus Right
Mean POC	-0.7100	0.7500
Standard Deviation	0.4501	0.3542
Number of Subjects	15.0000	15.0000

Table 11

Descriptive Statistics for the Factor of Stimulus Type in Hypothesis 3

Descriptive Statistic	Word	Affect
Mean POC	0.0543	-0.0066
Standard Deviation	0.8159	0.8216
Number of Subjects	30.0000	30.0000

Table 12

Descriptive Statistics for the Group x Stimulus Type Factor in Hypothesis 3

Descriptive Statistic	Lower Word	Lower Affect	Middle Word	Middle Affect	Higher Word	Higher Affect
Mean POC	0.13	-0.24	0.06	0.17	-0.02	0.08
Standard Deviation	0.90	0.82	0.86	0.94	0.79	0.86
Number of Observations	10.00	10.00	10.00	10.00	10.00	10.00

Appendix L

A Comparison of Positive and Negative Affective Stimuli

In order to assess whether positive affective stimuli (happy) varies from negative affective stimuli (sad and angry), an additional analysis was performed to compare happy mean total scores with the mean totals of angry and sad scores for Phase 1. A two-way mixed factorial MANOVA with the between subjects factor of verbal fluency (lower, middle, and higher) and the repeated measures factor of affect (positive and negative) was performed on Phase 1 data.

There were main effects of both Group, $F(2,42) = 5.45$, $p = 0.0001$, and Affect, $F(1,42) = 5.95$, $p = 0.0054$, for the LEA scores. There was no interaction. Tukey's HSD post hoc comparison revealed that the total correct for the left ear for Higher VF subjects ($M = 2.97$; $SD = 1.42$) was significantly greater than the total correct for the left ear for lower VF subjects ($M = 2.00$; $SD = 1.37$). In addition, Tukey's HSD post hoc comparison revealed that the total correct for the left ear for negative affective stimuli ($M = 2.87$; $SD = 1.10$) was significantly greater than the total correct for the left ear for positive affective stimuli (_M_ = 2.11; _SD_ = 1.65).

Similarly, there were main effects of both Group, F (2,42) = 2.65, _p_ = 0.0389, and Affect, F(1,42) = 8.64, _p_ = 0.0001 for the REA scores. There was no interaction. Tukey's HSD post hoc comparison revealed that the total correct for the right ear for Higher VF subjects (_M_ = 3.87; _SD_ = 1.14) was significantly greater than the total correct for the right ear for lower VF subjects (_M_ = 2.88; _SD_ = 1.56). In addition, Tukey's HSD post hoc comparison revealed that the total correct for the right ear for negative affective stimuli (_M_ = 3.62; _SD_ = 0.97) was significantly greater than the total correct for the right ear for positive affective stimuli (_M_ = 3.00; _SD_ = 1.47).

These findings are consistent with the previous analysis. Both approaches showed that subjects higher in fluency achieve greater LEA and REA scores than subjects lower in fluency. In addition, both approaches showed that LEA and REA scores were higher for the identification of negative than positive affective stimuli.

Appendix M

Analysis of Hypothesis 3 Using All Data

In the previous analysis of Phase 2, 15 subjects were discarded randomly so that there would be an equal number of five subjects in each of the fluency by focus groups. This analysis of Phase 2 is identical to the previous approach, however, no subjects are discarded and size of the fluency by focus groups vary from between five and eight people.

A three-way mixed factorial MANOVA with the between subjects factors of Fluency (lower, middle, and higher) and Focus (focus left or focus right) and the repeated measures factor of Stimulus Type (word or affect) was performed on the data from Phase 2. This MANOVA was performed under the General Linear Models (GLM) procedure to account for the unequal group sizes. A significant Focus x Stimulus Type interaction, $F(1,33) = 4.83$, $p = 0.0147$, was found using the LEA scores. Refer to Table 1. Similarly, A significant Focus x Stimulus Type interaction, $F(1,33) = 5.73$, $p = 0.0065$, was found using the REA scores. Refer to Table 2.

Table 1

Mean Total LEA Scores for the Focus x Stimulus Type Interaction

	Focus	
Stimulus Type	Focus Right	Focus Left
Word	3.12	11.90
Affect	3.05	15.00

Note. LEA scores represent the total correct for stimuli presented to the left ear.

Table 2

Mean Total REA Scores for the Focus x Stimulus Type Interaction

	Focus	
Stimulus Type	Focus Left	Focus Right
Word	4.55	14.63
Affect	2.70	13.68

Note. REA scores represent the total number correct for stimuli presented to the right ear.

Tukey's HSD post hoc comparison revealed that the focus left / affect condition (M = 15.00; SD = 4.42) was significantly greater than both the focus right / word condition (M = 3.12; SD = 4.67) and focus right / affect condition (M = 3.05; SD = 4.19) for the LEA scores. Similarly, the focus left / word condition (M = 11.90; SD = 4.09) was significantly greater than both the focus right / word (M = 3.12; SD = 4.67) condition and the focus right / affect (M= 3.05; SD = 4.19) condition for the LEA scores.

Tukey's HSD post hoc comparison also revealed that the focus right / word condition (M = 14.63; SD = 5.04) was significantly greater than both the focus left / word condition (M = 4.55; SD = 5.29) and the focus left / affect condition (M = 3.12; SD = 4.92) for the REA scores. Similarly, the focus right / affect condition (M = 13.68; SD = 3.61) was significantly greater than both the focus left / word condition (M = 4.55; SD = 5.29) and the focus left / affect condition (M = 3.12; SD = 4.92) for the REA scores.

For the LEA scores, main effects of Focus, $F(2,32) = 47.42$, $p = 0.0001$, and Stimulus Type, $F(2,32) = 5.75$, $p = 0.0074$, were obtained. Tukey's HSD post hoc comparison revealed that LEA scores for the focus left condition (M = 13.45; SD = 5.77) were significantly greater than the LEA scores for the focus right condition (M = 3.08; SD = 5.23). In addition, Tukey's HSD post hoc comparison revealed the LEA scores for affect (M = 9.18; SD = 7.62) were significantly greater than the LEA scores for words (M = 7.62; SD = 6.24).

For the REA scores, main effects of Fluency, $F(2,32) = 3.68$, $p = 0.0255$, Focus, $F(2,32) = 36.70$, $p = 0.0004$, and Stimulus type, $F(2,32) = 6.54$, $p = 0.0063$ were obtained. Tukey's HSD post hoc comparison revealed that the REA scores for subjects both higher (M = 10.07; SD = 4.05) and middle (M = 9.10; SD = 4.94) in fluency were significantly greater than the REA scores subjects lower (M = 6.55; SD = 4.34)in fluency. In addition, Tukey's HSD post hoc comparison revealed that REA scores for the focus right condition (M = 14.12; SD = 4.57) were significantly greater than the REA scores for the focus left condition (M = 3.63; SD = 5.51). Finally, Tukey's HSD post hoc comparison revealed the REA scores for words (M = 9.46; SD = 7.18) were significantly greater than the REA scores for affect (M = 8.05; SD = 6.49).

These findings are consistent with the previous findings for Hypothesis 3. Both types of analysis reported identical Focus x Stimulus Type interactions and main effects of focus and stimulus type for LEA scores. Similarly, both types of analysis reported identical main effects of focus for the REA scores. Unlike the previous analysis, however, a Focus x Stimulus Type interaction and main effects of fluency and stimulus type were obtained for the REA scores. These added results support previous findings and are due to the addition of more subjects in the analysis.

Finally, a three-way mixed factorial GLM with the between subjects factors of Fluency (lower, middle, and higher) and Focus (focus left or focus right) and the repeated measures factor of Stimulus Type (word or affect) was performed on the POC scores from Phase 2. Interestingly, there were main effects of both fluency, $F(2,33) = 3.96$, $\underline{p} = 0.0287$, and Focus, $F(1,33) = 119.35$, $\underline{p} = 0.0001$, for the POC scores using all Phase 2 data. No interactions were found. Tukey's HSD post hoc comparison revealed that subjects lower in fluency had a significantly greater left ear bias ($\underline{M} = -0.26$; $\underline{SD} = 0.87$) than subjects higher in fluency

(*M* = 0.12; *SD* = 0.78). In addition, Tukey's HSD post hoc comparison revealed that focus right instructions led to a significant right ear bias (*M* = 0.66; *SD* = 0.52), while focus left instructions led to a significant left ear bias (*M* = -0.68; *SD* = 0.38). Although the main effect of Focus was the same as the previous analysis, the main effect of group was not.

The main effect of group obtained in this analysis provides partial support for an important theoretical basis of this study, the Annet and Kilshaw (1984) right-shift hypothesis. This theory would predict that subjects having lower fluency scores would rely more on the right cerebral system than subjects subjects having higher fluency scores. Support for this theory was found only for the higher and middle fluency groups.

Appendix N

Data Analysis with Ear of Presentation as a Factor

To determine whether ear of presentation was a significant factor, analysis of both Phase 1 and Phase 2 data was repeated using the POC scores with ear as a factor. If the REA score was greater than the LEA score, a one was recorded in the column for ear of presentation. Conversely, if the LEA score was greater than the REA score, a two was recorded in the column for ear of presentation.

To assess Hypothesis 1, a three-way mixed factorial GLM with the between subjects factors of Fluency (lower, middle, and higher) and Bias (right scores greater or left scores greater) and the repeated measures factor of Stimulus Type (word or affect) was performed on all Phase 1 data.

In addition to a significant Fluency x Bias interaction, $F(2,69) = 3.88$, $p = 0.0253$, there were main effects of both Stimulus Type, $F(1,9) = 64.31$, $p = 0.0001$, and Bias, $F(1,69) = 64.82$, $p = 0.0001$, using the POC scores. Tukey's HSD post hoc comparison revealed that the left ear bias for subjects lower in fluency (M = -0.2779; SD = 0.3100) significantly differed from the right ear bias for subjects middle in fluency (M = 0.1172; SD = 0.0984). This finding provides partial support for the Annet and Kilshaw (1984) right-shift hypothesis, which proposed that subjects having lower fluency scores rely more on the right cerebral system than subjects having middle or higher fluency scores.

As with the previous analysis, Tukey's HSD post hoc comparison revealed that the POC scores for affect (M = -0.16; SD = 0.28) showed a significant left ear bias, while the POC scores for words (M = 0.0938; SD = 0.18) showed a significant right ear bias. Finally, Tukey's HSD post hoc comparison revealed that the POC scores for a right ear bias (M = 0.1422; SD = 0.2278) significantly differed from the POC scores for a left ear bias (M = -0.1974; SD = 0.2568).

To assess Hypothesis 2, a three-way mixed factorial GLM with the between subjects factors of Fluency (lower, middle, and higher) and Bias (right scores greater or left scores greater) and the repeated measures factor of Affect (happy, sad, angry, and neutral) was performed on half of the data from

Phase 1.

In addition to a significant Fluency x Bias interaction, $F(2,73) = 8.17$, $p = 0.0006$, there was a main effect of Bias, $F(1,73) = 119.09$, = $p = 0.0001$, using the POC scores. Tukey's HSD post hoc comparison revealed that the left ear bias for subjects lower in fluency ($M = -0.3452$; $SD = 0.4880$) significantly differed from the right ear bias for subjects higher in fluency ($M = 0.3380$; $SD = 0.0858$). Again, this finding provides partial support for the Annet and Kilshaw (1984) right-shift hypothesis. Tukey's HSD post hoc comparison also revealed that the bias right scores ($M = 0.1572$; $SD = 0.2759$) significantly differed from the bias left scores ($M = -0.4168$; $SD = 0.4257$).

To assess Hypothesis 3, a three-way mixed factorial GLM with the between subjects factors of Fluency (lower, middle, and higher) and Bias (right scores greater or left scores greater) and the repeated measures factor of Stimulus Type (word or affect) was performed on Phase 2 data. A significant main effect of bias, $F(1,26) = 328.17$, $p = 0.0001$, was found. There were no interactions. Tukey's HSD post hoc comparison revealed that the right bias scores (M =

0.7580; $SD = 0.2902$) significantly differed from the left bias scores ($M = -0.8173$; $SD = 0.2472$).

VITA

Name: Katharine Ann Snyder

Address: 750 Tall Oaks Drive
Foxridge Apt. 12200-G
Blacksburg, VA 24060

Phone: (703) 951-0127

Date of Birth: March 11, 1970

EDUCATIONAL BACKGROUND

1992-present — Virginia Polytechnic Institute and State University, Blacksburg, VA., Master's Program in Psychology.

1988-1992 — B.A., West Virginia Wesleyan College, Buckhannon, WV, Magna Cum Laude, Honors Program Graduate, Psychology Major, Biology Minor, Religion Minor.

TEACHING EXPERIENCE

1993-Present — Graduate Teaching Assistant for the undergraduate Nervous Systems and Behavior course and the graduate Biological Basis of Behavior course for David W. Harrison, Ph.D., at Virginia Polytechnic Institute and State University.

Summer 1993 — Graduate Teaching Assistant for Introductory Psychology for David W. Harrison, Ph.D., at Virginia Polytechnic Institute and State University.

1992-1993	Graduate Teaching Assistant for four Introductory Psychology labs at Virginia Polytechnic Institute and State University.
1992	Team taught Introduction to Psychological Experimentation at West Virginia Wesleyan College for Richard S. Calef, Ph.D.
1992	Lab teacher for the Learning and Memory class at West Virginia Wesleyan College for Michael C. Choban, Ph.D.
1991-1992	Psychology Department Animal Lab Assistant at West Virginia Wesleyan College.
1990-1992	Student assistant for Richard S. Calef, Ph.D., West Virginia Wesleyan College Psychology Dept.
1989-1990	Student Assistant for Peter J. Bercovitz, Ph.D., West Virginia Wesleyan College, Religion Dept.
1990-1992	Assistant for Advanced Experimental Psychology at West Virginia Wesleyan College for Richard S. Calef. Ph.D.
1990-1992	Assistant for Physiological Psychology at West Virginia Wesleyan College for Richard S. Calef, Ph.D.
1991-1992	Assistant for the Behavior Modification class at West Virginia Wesleyan College for Richard S. Calef, Ph.D.
1990-1992	Assistant for Introduction to Psychology at West Virginia Wesleyan College.

1989-1992	Computer assistant for Statistics for Psychological Research at West Virginia Wesleyan College for Michael C. Choban, Ph.D.
Summer 1990	Math tutor for learning disabled students at the A Plus Learning Center in Towson MD.
1989-1992	Academic Peer Counsellor at West Virginia Wesleyan College.
1988-1992	Psychology Tutor for dyslexic and learning disabled students at the West Virginia Wesleyan College Learning Center.

PUBLICATION

Snyder, K. A., Calef, R. S., Choban, M. C., and Geller, E. S., (1992). Frequency of verbal transformations as a function of word presentation styles. Bulletin of the Psychonomic Society, 30 (5), 363-364.

PRESENTATION

Snyder, K. A., & Calef, R. S. Frequency of verbal transformations as a function of word presentation styles. Paper presented at the West Virginia Psychological Association Convention, Cannan Valley, W.V. March, 1992.

CURRENT RESEARCH PROJECTS

1. The Neurobehavioral Correlates of Affect Perception as a Function of Verbal Fluency Classification.
   David W. Harrison, Ph.D., committee chair
   Helen J. Crawford, Ph.D., committee member
   Albert M. Prestrude, Ph.D., committee member

2. The Neurobehavioral Correlates of Speech Perception as a Function of Levels of Illumination and Verbal Fluency Classification. Bill Gorman, David W. Harrison, and Katharine A. Snyder.

3. Age differences in Behavioral Measures of Laterality within Bright and Dim Light Contexts. John D. Alden, David W. Harrison, and Katharine A. Snyder.

HONORS

Scholarships	Basal Burns Memorial Psychology Scholarship (1991-1992)
	WV Wesleyan College Music Scholarship (1988-1992)
	Calvin West scholarship (1988-1992)
	MD Senatorial Scholarship (1988-1992)
	National United Methodist Bass Scholarship (1988-1992)
	Baltimore United Methodist Conference Scholarship (1988-1992)
	Linthicum Heights United Methodist Church Scholarship (1988-present)

Who's Who Among American College Students (1990-1991)

Honoraries	Psi Chi (Psychology) Beta Beta Beta (Biology) Sigma Alpha Iota (Music) Mortarboard (Academic) Phi Kappa Phi (Academic) Omicron Delta Kappa (Leadership) Alpha Lambda Delta (Freshman Academic)

Graduated Magna Cum Laude from the WV Wesleyan Honors Program

Sigma Alpha Iota Outstanding Musical Scholar Award (Class of 1992)

West Virginia Wesleyan College Class Key Award (Class of 1992)

WV Psychological Association Undergraduate Research Award (1992)

OTHER WORK EXPERIENCE

1986-1988	Sales Clerk for Sears and Roebuck (Glen Burnie, MD)
Summer 1990	Counselor for Physicians Weight Loss Center (Crofton, MD)
Summer 1990	Various clerical and secretarial positions through Olsten Temporaries (Glen Burnie, MD)
Summer 1991	Daycare employee of Rev. Sharon Ford (Linthicum Heights Methodist Church)
Summer 1993	I Can't Believe It's Yogurt (Yerkes Johnson Student Center and University Boulevard locations of Blacksburg Virginia)

PERSONAL REFERENCES

Richard S. Calef, Ph.D., Psychology Dept. Chair at WV Wesleyan College, (304) 472-0357, 45 Carol Street, Buckhannon WV, 26201

Ruth A. Calef, Ph.D., Professor of Psychology and Director of Peer Counseling Program, (304) 472-0357, 45 Carol Street, Buckhannon WV, 26201

Michael C. Choban, Ph.D., Professor of Psychology and Computer Sci.,(304) 473-8095, 30 Boggess Street, Buckhannon WV, 26201

Sharon Ford, Rev., Minister and employer, Linthicum Heights United Methodist Church, 200 School Lane, Linthicum MD, 21090

Katherine R. Glenney, Ph.D., Professor of Psychology, (304) 473-8078, 30 Boggess Street, Buckhannon WV, 26201

Larry R. Parsons, Ph.D., Professor of Music, (304) 473-8466, 114 School Street, Bridgeport WV 26330