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**The effects of lateralized stimuli in a dual-task paradigm:
Implications for multiple resource theory**

Spielman, Steven Barry, Ph.D.

City University of New York, 1991

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**The Effects of Lateralized Stimuli
in a Dual-Task Paradigm:
Implications for Multiple Resource Theory**

by

Steven B. Spielman

A dissertation submitted to the Graduate Faculty
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Abstract

The Effects of Lateralized Stimuli in a Dual-Task Paradigm: Implications for Multiple Resource Theory

by

Steven B. Spielman

Adviser: Professor Wilma Winnick

Two experiments were conducted to evaluate a special case of multiple resource theory which proposes that the left and right hemispheres possess separate processing resources. Additionally, the factors most influential to the development of interference and facilitation effects under a combined tachistoscopic and dichotic dual-task were assessed. In Experiment 1 eight dextral subjects, four men and four women responded manually to unilateral tachistoscopic verbal (semantic and phonetic stimuli) and non-verbal (facial stimuli) presentations. A right visual field advantage was found for both semantic and phonetic stimuli while facial stimuli failed to demonstrate significant visual field differences. The visual accuracy scores obtained in Experiment 1 served as a baseline for comparison with the visual accuracy scores obtained under the tachistoscopic and dichotic dual-task in Experiment 2. Eighteen dextral subjects, nine men and nine women, were tested under the 36 different dual-task experimental conditions and 2 baseline conditions of Experiment 2. Ear of presentation (left ear, right ear), visual field of

unilateral visual presentation (left visual field, right visual field), type of visual stimuli (phonetic, semantic, facial), and location of the visual presentation in the one second interstimulus interval between the dichotic pair and binaural probe (0 ms, 460 ms, or 920 ms following the dichotic pair) were all systematically varied. The results indicate that: 1. As the processing requirements for the auditory and visual tasks became more dissimilar, processing interference declined; 2. Under very specific circumstances (i.e. facial visual presentations during LE auditory trials) performance during a dual-task may be enhanced above its single-task level; and 3. There appears to be some support for the premise that multiple processing resources and mechanisms are in operation and that those separate systems may reside in the left and right hemispheres.

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INTRODUCTION

We are continuously faced with situations and circumstances that require the encoding, processing and/or response to two events which occur either simultaneously or in close temporal succession. Under these conditions of divided attention, performance may decline on one or both tasks or be time shared effectively such that no decrement in performance is evident (Wickens, Sandry, & Vidulich, 1983; Vidulich & Wickens, 1981). It is even possible, under certain circumstances, that performance on one task may be augmented relative to its single task performance without effect on the secondary task (Kinsbourne, 1973).

This study has been designed to evaluate a subject's performance on a dichotic listening task while concurrently processing lateralized visual material. Ear of presentation, visual field of the unilateral visual presentation, type of visual stimuli (phonetic, semantic, facial), and temporal location of the visual presentation in the one second ISI between the dichotic pair and binaural probe were all systematically varied in order to study the effects of these variables on dual-task performance. The goals were two-fold: 1) to evaluate a special case of multiple resource theory which proposes that the left and right hemispheres possess separate processing resources; and 2) to determine the

factors most influential to the development of interference and facilitation effects.

Attentional Processing

To consider the inter-relationship of cognitive processes in individuals performing a divided attention task, it is important first to consider the qualitative distinction between controlled and automatic processing (Shiffrin & Schneider, 1977; Schneider & Shiffrin, 1977). Automatic and controlled processes are considered to be the major components of a two-process theory of human information processing. They represent processes which insure the efficient analysis of information. Where automatic processing is thought to occur very rapidly, fairly effortlessly, not to be restricted by capacity limitations in short term store and not directly under subject control, controlled processes are believed to be limited in capacity, effortful in nature and requiring the serial analysis of information. Automatic processes require extensive training to develop (Spelke, Hirst, & Neisser, 1976) and once learned are extremely difficult to modify (Dyer, 1973; Shiffrin & Schneider, 1977, Exp. 4d; Logan, 1980). These automatic processes are believed to utilize a relatively permanent set of associative connections in long-term store which enter short-term store only as the automatic sequence is activated (Shiffrin & Schneider, 1977). This would imply that these automatic sequences should then cause interference

with ongoing controlled processing as controlled processing is seen as occurring in short-term store. Shiffrin and Schneider (1977), however, believe the activation to be extremely brief and unless the automatic sequence has an attention-calling response that the information will be lost from short-term store and not interfere with ongoing controlled processing. Shiffrin and Schneider (1977) believe that "dividing attention is possible when the targets have been consistently mapped during training until automatic detection operates" (page 186). They suggest that automatic processes often seem to occur in parallel and may appear to be independent of each other. Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977) make an important distinction between stimuli and responses that are consistently mapped and those that are variably mapped. A task would be considered to be consistently mapped if the subject makes the same overt or covert response to the stimulus across training trials. In order to achieve consistent mapping, Schneider and Shiffrin (1977) employed relatively simple stimuli (digits or consonants), a memory set of one or four stimuli, and between 1500 and 2100 training trials. When the response requirements change across training trials the stimuli and responses are variably mapped. Shiffrin and Schneider (1977) believe that under variably mapped conditions practice should have little impact on performance and no automatic

process should develop and the task will continue to require controlled processes.

In contrast to automatic processing, controlled processing has a limited capacity and is believed to utilize short-term store. It is subject-regulated, in that the individual can direct and allocate the processing resources to changing task parameters. According to Shiffrin and Schneider (1977) "because active attention by the subject is required, only one such sequence [of nodes] at a time may be controlled without interference, unless two sequences each requires such a slow sequence of activations that they can be interwoven serially" (page 156). Shiffrin and Schneider (1977) suggest that deficits in divided attention tasks arise because of limitations in controlled processes, particularly due to the limited rate of serial comparisons. Where automatic processes can occur in parallel, controlled processes cannot.

Although Shiffrin and Schneider (1977) believe controlled processes can only be performed serially, they suggest that automatic and controlled processes can proceed in parallel with one another. In addition, the output of an automatic sequence can serve as the input into a serial controlled processing sequence in the later stages of information processing suggesting that a task may require a combination of both automatic and controlled processes prior to task completion. It would

then be expected that, in a dual-task similar to the present study, performance should vary considerably depending on the degree of controlled versus automatic processing required by each individual task.

Dual-Task Theory

In the 1950s and 1960s, research conducted by Broadbent (1958), Treisman (1964), and others indicated that simultaneous dual channel auditory verbal input greatly limited attentional processing. From these early dichotic listening experiments evolved the discussion of a "structural" limitation present in the attentional system. This "bottleneck", as it came to be known, was felt to narrow a parallel processing system to a point where analysis occurred serially. Different theorists placed this bottleneck in varying locations along an information processing continuum and ascribed to it a variety of functions. Broadbent (1958) argued that this bottleneck occurred early on in the processing of stimuli. He believed that two stimuli occurring simultaneously are stored temporarily in a sensory buffer. Based on the physical characteristics of the message a filter then allows one message through while the second is held in the sensory buffer. Broadbent (1958) views the filter as preventing the overloading of a limited-capacity system that is involved in further processing the incoming stimuli or message.

Treisman (1964) modified Broadbent's (1958) theory

to feature an attenuation rather than a rejection of unattended information. She, in addition, viewed the location of the bottleneck as being flexible. Within this framework she describes a hierarchy of analyses whereby physical cues and specific sounds at the early stages of the hierarchy, progress to the analysis of grammatical structure and meaning in the later stages of the hierarchy. The extent of analysis within this hierarchy is based on the availability of capacity to process all of the message. Under conditions of high processing load in a shadowing task the unattended information would not be processed beyond an early stage in the proposed hierarchy.

Kerr (1973) proposed a further modification of the bottleneck model in which a single limited capacity central mechanism (LCCM) limits the ability of the individual to perform simultaneous tasks which share identical operations. This hypothesis includes the notion that not all mental operations will require access to this limited capacity mechanism, while other operations will always require access. Kerr proposes that the mental operations that do not require the utilization of this mechanism may proceed in parallel without interference between the two operations. When interference does occur, it seems most often to involve overlapping demands on specific subsystems (e.g. the verbal system: Allport, Antonis, & Reynolds, 1972). Kerr

further proposes that the LCCM may be either a short single channel mechanism that operates serially or a system capable of processing parallel inputs with reduced efficiency.

The theories discussed above are somewhat mechanistic in nature, in that they imply a structural mechanism which reduces the capability of the individual in dual-task situations. Although some of these theories consider issues of "capacity", it is viewed primarily as a concept that implies the use of the "bottleneck" mechanism or process for a longer period of time. The following theories take a somewhat different view of attentional processes. They view capacity as being divisible in graded quantities to separate tasks rather than being limited to performing only one task at a time. Moray (1967) saw this capacity or resources as being available to perform operations at any stage of processing. He proposed that a bottleneck need not exist but rather interference would occur from the capacity demands at specific stages of processing.

Kahneman (1973) proposed a model of attention allocation. Within this model attention is viewed as a limited resource that can be utilized very flexibly. Kahneman's model puts forth the idea that people can change their attentional allocation policy from moment to moment as the situation requires. According to the model, individuals can focus all of their attention on

one activity or attention can be divided among a number of activities. The allocation policy can be influenced by a number of factors which Kahneman refers to as: enduring dispositions, momentary intentions, and evaluation of demands on capacity. These refer to attention being allocated based on well-learned rules, conscious decisions, and task difficulty, respectively. Kahneman's (1973) model clearly views attentional capacity as originating out of a single resource pool although with the ability to be parceled out among several tasks.

Norman and Bobrow (1975) have also discussed limitations in processing resources as impacting on task performance. However, they make a distinction between performance which is affected by limitations in resources and performance which is affected by data limitations. Norman and Bobrow (1975) view resource limited processes as meaning that an increase in the amount of resources devoted to a task would result in an increase in performance efficiency. Performance which is data-limited implies that the further channelling of resources to the task will not result in increased performance. Norman and Bobrow suggest that two tasks occurring together should not interfere with each other as long as the total processing need does not exceed the total resources available. They proposed the principle of complementarity which suggests that when two or more

tasks are performed simultaneously they utilize all the capacity of the system such that an increase in resources to one task results in an equal decrease in resources to the other task. This principle is based on the assumption that concurrent tasks will compete for a single pool of resources.

Wickens (1984) sees single resource theory as being inadequate in explaining many of the outcomes seen in dual-task research. He proposes a multiple-resource theory which is an extension of the work of Navon and Gopher (1979) and others. Wickens (1984) views a single resource model as being unable to explain four experimental phenomena: difficulty insensitivity, perfect time-sharing, structural alteration effects, and difficulty-structure uncoupling.

This multiple resource model views resources in a "three-dimensional metric consisting of stages of processing (perceptual-central versus response), codes of perceptual and central processing (verbal versus spatial), and modalities of input (visual versus auditory) and response (manual versus vocal)" (Wickens, 1984, pg 79). The differentiation between the resources in the stages of processing level comes for tasks that require more cognitive or perceptual processing versus those tasks that are response demanding. Isreal, Wickens, Chesney, and Donchin (1980) utilizing a P300 evoked potential paradigm demonstrated that P300

amplitude was influenced by a concurrent task which altered the display load. However, P300 amplitude was unaffected by the requirement to initiate a manual response or alter the frequency of response in a concurrent tracking task (Isreal, Chesney, Wickens, and Donchin, 1980). Wickens (1984) suggests that this latter finding is more indicative of a response stage and so draws upon a separate resource pool as compared to the more "central processing" resources required in the P300 discrimination task.

The second factor in Wickens' three dimensional matrix relates to the differentiation between the processing requirements for verbal and spatial information. Much of this work has been performed by Kinsbourne and his colleagues and will be discussed further below.

Lastly, Wickens (1984), within his human processing resources matrix, indicates that both the modalities of input (visual and auditory) and response (manual and vocal) each have access to separate resources. A number of studies (Isreal, 1980; Martin, 1980; Rollins & Hendricks, 1980) indicate that cross-modal presentations do provide an advantage over intramodal presentations.

Friedman and Polson (1981) propose an interesting theory similar in many respects to the multiple-resource model described by Wickens (1984) and particularly relevant to the present study. Within their theory is

the premise that the cerebral hemispheres possess mutually inaccessible supplies of resources. As with Wickens' (1984) multiple-resource model, Friedman and Polson believe subject-task parameters (Navon & Gopher, 1979) determine the types of resources demanded by a specific task or tasks. These subject-task parameters, as described by Navon and Gopher (1979), may relate to the task (e.g. sensory quality of stimuli, predictability of stimuli, response complexity), the environment (e.g. signal to noise ratio), or the permanent or changing aspects of the subject (e.g. manual dexterity, level of practice). The combination of these subject-task parameters represent the constraints imposed on the resource system by the encounter of the specific task or tasks and the individual subject. Friedman and Polson (1981) refer to the particular subset of resources required for each task as its resource composition. They suggest, based on the work of Newell (1980), that a task can be performed utilizing a number of different resource compositions. When the concept of multiple resources is then combined with the flexibility possible in resource composition a dynamic system arises in which either complete, partial, or no overlap in the resource supplies demanded by any two tasks exists. The principle of complementarity (Norman & Bobrow, 1975) could then apply only if the two tasks could be performed with one particular combination of resources and no concurrence

cost (Navon & Gopher, 1979).

Friedman and Polson (1981) indicate that as the composition of resources and mechanisms that are required by two tasks become more similar, the overlap in resource demand increases and so mutual interference becomes likely and overall task performance declines. This picture is clouded, however, by the possible selection by the subject of alternative resource compositions which have the least amount of resource overlap when the tasks are combined. The potential implication is that single tasks, whose proposed resource compositions appear to be very similar, may, when combined, utilize alternate compositions with a reduced degree of overlap confusing the single to dual-task comparison.

In an attempt to explain the multitude of research findings with dual-task paradigms, Friedman and Polson (1981) have proposed that each cerebral hemisphere contains a separate array of mechanisms whose operation is dependent upon available resources. The supply of resources within each hemisphere is thought to be fixed and limited in its total capacity, able to be parceled out to any mechanism within the hemisphere and yet completely inaccessible to the other hemisphere. It is further proposed that these different mechanisms residing in each hemisphere are utilized by a variety of perceptual, cognitive, and motor processes and these processes are drawing from a fixed resource pool. The

result of these processes performed within the hemisphere may become available either as input to other processes within that hemisphere or transferred via the callosum to the opposite hemisphere. Friedman and Polson (1981) have made a distinction between mechanisms and resources so as to allow for the possibility of both structural and capacity interference.

Lastly, Friedman and Polson (1981) have hypothesized that the hemispheres cannot have differential levels of arousal. They suggest that whenever the resource allocation is increased so that the hemisphere primarily involved in the processing of a task has sufficient resources to attain a desired performance level, then the resources of the opposite hemisphere will increase by an equal amount up until its fixed limit. This additional resource may potentially be available to increase the performance of the task being processed by the opposite hemisphere and so help to explain instances of facilitation in dual-task research (e.g. Kinsbourne & Lock, 1971).

Empirical Findings

To date, a number of studies have investigated the variations in response under single and dual-task demands (e.g. McFarland & Ashton, 1978; Allard & Bryden 1979; Bowers & Heilman 1980; Hellige & Wong 1983). Wickens, Mountford and Schreiner (1981) found that there are multiple factors that can affect response latency and

accuracy. Those factors include modality of the input and output (visual vs. auditory, vocal vs. manual) and the type of information (verbal vs. spatial). Wickens (1984) elaborated on these factors within his three-dimensional processing matrix and added a stages of processing component which makes the distinction between perceptual-central processing and response generation. When two separate tasks are joined in a dual-task paradigm, performance typically declines on one or both tasks although a qualitative effect on performance also may occur as demonstrated by Kinsbourne (1973). He reported that visual field advantages could be changed depending upon the type of memory load the subject was required to retain. Facilitative effects are also possible when lateralized stimuli are presented tachistoscopically during a dichotic listening paradigm (Spielman, 1979).

A study by Rollins and Hendricks (1980) utilizing similar types of verbal stimuli as those employed in the present study, found that significant declines in performance occur when a subject is required to make a determination regarding the acoustic properties of a word simultaneously with the processing of an auditory message. However, a categorization procedure, which appeared to require more semantic analysis, did not demonstrate any interference effects on Rollins and Hendricks (1980) shadowing task. Rollins and Hendricks (1980) did not, however, employ lateralized presentation

of the intervening task, as was utilized in the Spielman (1979) study, which demonstrated significant interaction effects between stimulus material and visual field. Based on the results of Fisk and Schneider (1983), it is possible that the categorization procedure employed by Rollins and Hendricks (1980) drew mostly on automatic processes thereby reducing the need for resources from a limited controlled resource pool and so eliminating any interference effect. Alternatively, the semantic material may have utilized non-redundant mechanisms allowing the primary task to proceed without interruption.

A number of authors have examined the facilitation and/or interference effects of concurrent stimuli using verbal and/or non-verbal material. Kinsbourne (1973) demonstrated that visual field advantages could be changed from right visual field to left visual field depending upon the type of memory load. When the stimulus was a string of words, a RVF advantage developed for the concurrent task of detecting the location of a gap in a square. However, when this same concurrent task was used with the memory load changed to holding a melody in memory, a LVF advantage was seen (Kinsbourne, 1973). Hellige and Cox (1976) also using a verbal memory load have confirmed this priming effect for the left hemisphere (LH). However, Hellige, Cox, and Litvac (1979) were unable to show right hemisphere (RH) priming

with a spatial memory load. This failure to show a priming effect may have been due to the method and type of test stimulus employed (matrix reproduction). Employing a series of concurrent tasks with five commissurotomed patients and eight normals, Franco (1977) found that the split brain subjects were unable to read while sorting with their right hands and were unable to whistle while sorting with their left hands. These tasks presented no difficulty for normal subjects.

Spielman (1979) using a combined dichotic listening and unilateral visual presentation paradigm demonstrated that both right and left hemisphere activation could occur. Employing two different dichotic tapes (consonant-vowel syllables and complex tones) and two types of visual stimuli (four letter concrete nouns and Identi-Kit produced faces), Spielman (1979) reported higher accuracy on the dichotic listening task when a visual stimulus was combined with its preferred visual field (e.g. words shown in the RVF and faces shown in the LVF). This effect was seen for both the consonant vowel syllables and for the complex tones. It was suggested that the priming effects may be the result of a general congruent pattern of activation produced in the hemisphere "specialized" for each type of visual material. This suggestion agrees with the statement by Hellige et. al. (1979) that "...it is likely that concurrent tasks do, to a certain extent, influence the

level of activation of both hemispheres in a similar manner" (p. 273) and is similar to the theory proposed by Friedman and Polson (1981). It is important to note that these tasks were truly concurrent and not a type of priming, i.e. the visual stimuli did not precede the auditory stimuli. Based on the possibility that the simultaneous nature of the tasks had some interfering as well as facilitating effect, the present study contains three different pre-binaural probe visual conditions.

Spielman (1979) showed that in addition to the facilitation effects obtained when a visual stimulus was paired with its preferred visual field (words to the RVF and faces to the LVF), strong interference effects were observed when the reverse combinations were shown (words to the LVF and faces to the RVF). A difference in dichotic listening accuracy of approximately 15% was found between a RVF verbal presentation and a LVF verbal presentation for the CV-syllables. This difference may be the result of a "bottleneck" at the processing mechanisms similar for both the auditory and visual verbal tasks. Alternatively this interference may result from the allocation of more processing resources by the LH to interpret the degraded or poorly encoded signal being transferred from the RH and thereby exhausting the available LH resource supply. A third alternative is that an incongruent pattern of activity results from the encoding or processing of a visual stimulus in its non-

preferred hemisphere. This possibility exists because the facilitation and interference patterns for both dichotic tapes are very similar.

Allard and Bryden (1979), using two dichotic tapes (CV syllables and environmental sounds) and two sets of visual material (verbal and nonverbal), found that the memorization of a verbal set prior to a CV dichotic presentation caused an increase in the RE advantage. Surprisingly, however, memorization of a nonverbal set increased the RE advantage to a greater extent. The LE advantage for nonverbal dichotic material decreased for the nonverbal visual set and remained the same for the verbal set. In contrast, Hellige and Wong (1983) using right-handed subjects found that a six word memory load caused a decrease in RE recognition scores on a CV dichotic task in subjects who displayed a RE advantage during baseline measurement. Subjects who demonstrated an initial LE advantage had decreased recognition scores for LE CV trials while RE accuracy was unchanged. This intersubject variability even in an all right-handed population is an important factor to consider in interpreting laterality data of this nature.

Bowers and Heilman (1980) employed verbal and nonverbal warning stimuli and found that the asymmetrical activation effects displayed were linked to a decisional process present in the experimental paradigm. The authors used a center fixation stimulus consisting either

of a three-letter concrete noun or a face from a college yearbook. Their two primary conditions were a Go/No-go reaction time condition and a simple reaction time (RT) condition. No asymmetries were found for the simple RT condition. However, when the response was linked to a decisional process (if the word or face belonged to a target set) then asymmetries were detected. These asymmetries took the form of shorter RTs with a word warning stimulus when the right hand was used for responding in contrast to when the left hand was used. When face warning stimuli were used, no significant advantage was detected, although there was a 9 ms. advantage in the expected direction (the left hand was faster than the right). Bowers and Heilman propose that with nonverbal stimuli the RH activates the LH more than the LH activates the RH during the presentation of verbal material. They describe this process as asymmetric interhemispheric activation. Bowers and Heilman (1980) found greater asymmetries in the expected direction with their more complex condition and hypothesized that "a response-linked decisional judgement is critical for inducing asymmetric activation" (p. 315). It is possible that these asymmetries are not so much response-linked but rather are due to the degree of processing which is necessary for their Go/No-go RT condition. There is additional experimental and clinical evidence to support this hypothesis (Heilman & Watson, 1977; Heilman & Van

Den Abell, 1979).

Semantic priming (e.g., Swinney, Onifer, Prather, & Hirshkowitz, 1979; Sperber, McCauley, Ragain, & Weil, 1979) and phonetic priming (e.g., Hillinger, 1980; Tanenhaus, Flanigan & Seidenberg, 1980; Humphreys, Evett & Taylor, 1982; Neely, 1976) have been demonstrated, although priming of phonological processing with semantic stimuli has not been studied. It would appear though, that the prime does not have to be restricted to a specific type of linguistic material (e.g., semantic) in order to be an effective facilitative agent (Kinsbourne, 1973; Spielman, 1979). Moscovitch and Klein (1980) suggest that when a given hemisphere is functioning at a level below that which it is capable, a concurrent task that does not deplete the resources of the hemisphere specialized to perform it may raise the resource level of that hemisphere. As a result the tasks are processed more efficiently and performance, in theory, may be improved. Moscovitch and Klein (1980) caution that this effect is obtained under restricted conditions, when the hemisphere is operating below capacity and when the demands made by the primary and secondary tasks do not exceed the total resources of the hemisphere. These material-specific effects on verbal processing were examined in the present study.

Previous studies have relied either exclusively or heavily upon response latency measures as determinants of

hemispheric activation. As in the Spielman (1979) study the present study employed both an accuracy measure and a reaction time measure as dependent variables for a CV dichotic task. The rationale is that an accuracy measure is more indicative of higher level processing than is RT, which seems to simply reflect a readiness to respond. It is expected that the accuracy measure will provide another means of examining lateralized dual-task performance.

Laterality Effects

A major premise of the present study is that multiple processing resources are present with the left and right cerebral hemispheres possessing separate processing resources and mechanisms. As the Spielman (1979) study demonstrated, merely presenting verbal and non-verbal material to be processed in a dual-task paradigm would not be sufficient in scope to view all the relevant factors impacting on resource allocation during a dual-task. Hemisphere of stimulus delivery also produced significant effects on dual-task performance (Spielman, 1979). If indeed it is assumed that lateralized verbal and non-verbal stimuli are necessary in order to most effectively access these separate resources, then a review of the single-task laterality research for the stimuli employed in the present study is relevant at this juncture.

In a comprehensive review of the divided visual

field literature over the past decade Beaumont (1982) states that "for the purpose of this review, I shall assume that with unilateral presentation of English words at between 2 degrees to 5 degrees of visual angle for less than 180 ms., a right visual field (RVF) advantage is to be observed in accuracy and reaction time for identification or matching" (p. 58). There are certain specific aspects of this RVF advantage for verbal material that are relevant to the present study. Gross (1972) found handedness and same/different matching to have no effect on the RVF advantage demonstrated by 3-letter words. In a study employing unilateral presentation of concrete nouns, Hines (1976) found a greater RVF advantage to exist for unfamiliar concrete nouns (a frequency of 14.75 per million) than for familiar concrete nouns (at least a frequency of 100 per million). In the Hines study no statistical tests were performed on the unfamiliar word and familiar word groups in order to determine the significance on the RVF advantage. The results from visual phoneme matching have been less conclusive. Moscovitch (1976) has found a RVF advantage for vowel sound matching when "same" responses were required. However, Umilta, Forst & Hyman (1972) demonstrated a RVF advantage for consonant-vowel discriminations and a left visual field (LVF) advantage for the matching of vowel sounds. Day (1977) reported a RVF advantage for category judgements to nouns for

abstract categories (e.g. feelings) but not for concrete categories (e.g. animals).

Verbal material has consistently been shown to display a RVF advantage; however, a stimulus that produces a consistent LVF advantage has been more elusive. In the past 15 years, research has confirmed clinical findings that the right hemisphere is involved in the recognition of faces (e.g. prosopagnosia; De Renzi and Spinnier, 1966). Rizzolatti, Umilta and Berlucchi (1971), using faces as targets, found a LVF advantage for the identification of targets and non-targets regardless of hand of response. This LVF advantage appears to be indicative of a processing advantage in the right hemisphere (RH). Geffen, Bradshaw, and Wallace (1971), using faces constructed from an Identi-kit (a device used in the construction of facial likenesses), found that reaction times to faces presented to the LVF were shorter than to the faces in the RVF. Geffen et. al (1971) employed a same/different paradigm with target and non-target faces. Facial recognition has not only been shown to produce a LVF advantage under conditions of a target memory load but also when two faces were sequentially presented (Moscovitch, Scullion, & Christie, 1976). Using verbal or musical priming, Schwartz and Smith (1980) found the LVF advantage for chimeric faces to be independent of these priming effects.

In 1961, Kimura, working with subjects with left

temporal lobe damage, found that their performance on a dichotic digits task was below the performance level of subjects with right temporal damage. Springer, Sidtis, Wilson and Gazzaniga (1978) found that six, split-brain patients all displayed a large right ear (RE) advantage for the recognition of consonant-vowel (CV) syllables. Research with normal subjects has also shown that dichotically presented CV syllables display a RE advantage (Studdert-Kennedy & Shankweiler, 1970).

The present study employed the same CV syllable dichotic stimuli used in the Springer et. al. (1978) study although the interstimulus intervals were reduced in order to be consistently at one second. In the Spielman (1979) study the facilitation effects may have been reduced due to the simultaneous nature of the stimulus delivery. The present study employed three different stimulus onset times for the intervening visual task to better examine the temporal relationship of the facilitation and interference effects. With a one second inter-stimulus interval between the dichotic pair and binaural probe, three temporal locations were chosen to provide conditions which would relate to early and later stage information processing. As noted above, many studies have examined the patterns of interference or lack of interference occurring under concurrent task demands. Fewer studies, however, have addressed the facilitation effects that can also occur during

concurrent tasks. The present study consists of two separate experiments which have been designed to evaluate: 1) the presence of independent processing resources and mechanisms within the left and right hemisphere while; 2) examining the critical factors which either restrict or promote these resources and mechanisms to operate independently. Previous studies (Heilman & Van Den Abell, 1979; Rollins & Hendricks, 1980; Friedman, Polson, Dafoe, & Gaskill, 1982; Galluscio, Kuehner, & Van Buskirk, 1984; Herdman & Friedman, 1985) have all used non-lateralized stimulus presentations for at least one of their tasks. Spielman (1979) employed lateralized stimulus presentations for both the primary and concurrent task. It was determined that interactions existed between the hemisphere of stimulus presentation of the two tasks suggesting that the utilization of non-lateralized tasks may not fully consider all the pertinent variables when assessing the presence of independent mechanisms and resources in the left and right hemisphere. Moscovitch and Klein (1980) propose that much of the decline in performance which occurs during a dual-task results from interference "relatively early in processing" (page 599). Presenting a memory load as either the primary or concurrent task, as the studies above have done, fails to accurately consider all the variables leading to interference effects while also not assuring the establishment of conditions specific

enough to result in facilitation.

Aim of Study

The aim of Experiment 1 was to determine the extent of the asymmetries between LVF and RVF presentations for the three types of visual stimuli (phonological interpretation, semantic categorization, and facial analysis). Only visual presentations were employed so as to serve as the single task control for comparison to the visual task portion of the dual-task in Experiment 2. Experiment 2 combined the visual stimuli from Experiment 1 with a consonant-vowel dichotic task to provide the conditions necessary to determine dual-task performance. The visual stimuli were presented at one of three times (based on the experimental condition) after the dichotic pair and prior to the binaural probe.

Altering the visual onset times (0 ms., 460 ms., and 920 ms., after the dichotic pair), allows an examination of the temporal relationship involved in the generation of interference and facilitation effects. It is predicted that as one moves along the ISI continuum from the 0 ms condition to the 460 ms condition to the 920 ms condition interference should decline for the verbal stimuli (phonetic and semantic) as the simultaneous sharing of redundant processing mechanisms becomes less necessary. In contrast, the facial stimuli, if indeed they do not share the same mechanisms as those required for processing of the CV dichotic task, should not

demonstrate any interference along this continuum and present with consistent performance levels for all three conditions at or near baseline.

The visual stimuli employed differed in their similarity to the CV dichotic task with the phonetic visual stimuli being most similar in their predicted resource composition. The semantic stimuli would be predicted to be the next in terms of similarity and the facial stimuli should be the most dissimilar in their resource and processing mechanism requirements. If this predicted similarity hierarchy exists and multiple resources are indeed present, then it is predicted that under dual-task conditions phonetic stimuli will result in the greatest degree of interference, with the semantic stimulus condition resulting in moderate levels of interference, and the facial stimulus condition being at or above baseline levels.

As discussed above, the majority of the previous studies (e.g. Rollins & Hendricks, 1980; Herdman & Friedman, 1985) have utilized at least one non-lateralized task within their dual-task paradigms. The present study with both tasks having lateralized presentations would be predicted to demonstrate reduced levels of interference when the auditory task and visual task do not share early stage processing in the same hemisphere (e.g. RE auditory trial and LVF visual presentation). Both speed and accuracy advantages would

be predicted under those conditions which utilize opposite hemispheres rather than sharing early stage processing in the same hemisphere.

GENERAL METHODS

Subjects

The study tested eight subjects (four males, four females) in Experiment 1 and 18 subjects (nine males, nine females) in Experiment 2, all with English as their native language. The subjects ranged in age from 18 to 28 years old. All were right-handed (as determined by a handedness questionnaire - Appendix A), with normal or corrected to normal vision as determined by self-report, and normal hearing also determined by self-report. Each subject read and signed a consent form (Appendix B) prior to beginning the study.

Subjects participated in two, one-hour sessions, for which they were paid \$10.00. Half of the subjects were shown slides in the semantic and facial category in the first session and phonetic and facial in the second session, while the remaining half had the reverse order.

Apparatus

The visual stimuli were presented by rear projection using a Ralph Gerbrands Projection Tachistoscope. The tachistoscope was started by a Schmitt trigger adjusted to trigger at either 0 ms, 460 ms, or 920 ms after the offset of the dichotic pair although prior to the onset of the binaural probe. The Schmitt trigger also started a Lafayette Instruments Co. Model 54419 LED counter (adjusted to measure to the nearest ms) simultaneously with the onset of the binaural probe. A double pole

double throw center return switch was used to halt the reaction time counter. All testing took place in a sound attenuation booth.

Material

The visual materials were 480 35mm slides containing either a word or a face to the left or right of a small black fixation point positioned on the projection screen. For each testing session a total of 160 trials (10 practice, 150 experimental) for a verbal stimulus category (semantic or phonetic) and 80 facial trials (6 practice, 74 experimental) were used. During the course of the two testing sessions each subject viewed a total of 150 semantic, 150 phonetic, and 148 facial experimental trials, in addition to 10 semantic, 10 phonetic, and 12 facial practice trials. The angle between the fixation point and the center of the word or face was 3.5° . Thirty-two different five-letter words were used ten times (including practice trials): eight words required a "yes" response based on whether they were related to the semantic category "four-legged animals". Eight other words required a "yes" response as they contained the correct phoneme: "f" as in the words phone, frost, and graph. The remaining 16 words did not fit either criterion. All words were made up of black letters against a white background. The words in the semantic group had an average frequency in the English language of approximately 25 per million while the

phonetic word group had an average frequency of approximately 24 per million (see Appendix C) [Thorndike & Lorge, 1944].

The faces were eight happy and eight sad faces chosen from a total of 27 sets of happy and sad faces. Photographs for the facial stimuli were taken on 35mm black and white film and included the clinical and clerical staff of the Department of Cognitive Rehabilitation of the John F. Kennedy Medical Center. Each picture was taken at a distance of six feet with the staff member standing against a white background. Half of the staff members were first told to make a happy face and then a sad face while the other 15 staff members were given the reverse order. Following the developing and printing of the film, 27 sets of happy and sad faces were shown to four individuals unfamiliar with any of the staff members. Three sets of the original 30 were eliminated due to a lack of picture clarity. The remaining 27 sets were rated on 'ease of discrimination between the happy and sad face'. The rating scale ranged from one for "very hard to discriminate" to seven for "very easy to discriminate". Total scores were tallied for each of the 27 sets, and those sets with the eight highest scores were chosen for inclusion in the study.

These eight sets of pictures were then trimmed so that only the faces remained. The faces were then placed on a white background and 35mm slides were made. All

slides were Kodak Ektachrome 64. Each of the 16 faces were used ten times during the course of the two sessions.

EXPERIMENT 1

The purpose of Experiment 1 was to have the four male and four female subjects provide baseline visual accuracy scores for comparison with the visual accuracy scores obtained under dual-task conditions in Experiment 2. In addition, visual field advantages for both accuracy and reaction time were determined for the three types of visual stimuli (semantic, phonetic, facial).

Method

Subjects: Eight subjects (four males, four females), all having met the criteria described in the General Methods section, participated in Experiment 1 only.

Materials: The visual stimuli were 480 35mm slides containing either a word to the left or right of a fixation point or a face to the left or right of a fixation point.

Procedure: In this experiment, lateralized visual stimuli were presented at 3.5° to the left or right of a center fixation point. At the conclusion of 16 practice trials there were a total of 224 trials per subject per session, 112 left visual field (LVF) and 112 right visual field (RVF) stimuli that had been randomly ordered using a random numbers table. Of the 224 trials, two-thirds of the visual stimuli were words and one-third were faces also randomly ordered using a random numbers table.

Randomization was first performed to find the visual field of presentation followed then by the random ordering of the verbal and facial stimuli. Prior to the beginning of Experiment 1 the subject was instructed to press a button which stopped a reaction time counter whenever one of the following three conditions (only two of the categories were used per session) was met by the visual presentation (duration - 60 ms): 1) If the word belonged to the semantic category of "four-legged animals"; 2) If the word presented had an "f" sound in it (ex. phone, alpha, graph); or 3) If the face shown during the study was a happy face and not a sad face. These three response categories were referred to as semantic, phonetic, and facial, respectively. The dependent measures were percent correct and reaction time.

Results

Tables 1 and 2 present the overall cell means and cell means by gender, respectively and demonstrate that there is a consistent RVF advantage across gender for the semantic and phonetic stimuli while facial stimuli demonstrate a LVF advantage for males and a RVF advantage for females.

Visual field effects. Two three factor mixed design analysis of variances (ANOVA) [Sex x (VF x VT)]; one utilizing accuracy data and the second reaction time data were used to test for significant visual field differences. A significant main effect for visual field was found [$F(1/6) = 14.86, p < .009$], with stimuli presented in the right visual field (RVF, 659 ms) demonstrating a speed advantage over left visual field (LVF) presentations (709 ms). The ANOVA performed for accuracy did not demonstrate a significant visual field difference. T-tests compared LVF and RVF accuracy and reaction time scores on each of the three visual types with the following results:

- 1) the semantic stimuli demonstrated a RVF advantage for both accuracy (4%) which approached significance ($p > .07$) and reaction time (99 ms) which was significant [$t(7) = 2.6827, p < .04$];
- 2) the phonetic stimuli also exhibited a non-significant RVF advantage for accuracy (2%) and

TABLE 1
Data Summary
Experiment 1 (across sex)

	SEMANTIC	PHONETIC	FACIAL
LVF	89.0% 742ms	84.8% 686ms	66.4% 714ms
RVF	93.0% 643ms	86.6% 623ms	66.8% 724ms

Accuracy	Reaction Time
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LVF = Left Visual Field
RVF = Right Visual Field

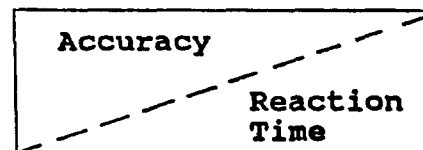
TABLE 2
Data Summary
Experiment 1

Males

	SEMANTIC	PHONETIC	FACIAL
LVF	89.8% 645ms	81.5% 661ms	75.3% 629ms
RVF	92.4% 557ms	83.7% 634ms	73.6% 690ms

Females

	SEMANTIC	PHONETIC	FACIAL
LVF	88.2% 839ms	88.1% 710ms	57.5% 798ms
RVF	93.6% 729ms	89.5% 612ms	60.1% 757ms



LVF = Left Visual Field
RVF = Right Visual Field

reaction time (63 ms).

- 3) facial stimuli demonstrated equivalent accuracy levels for both left and right visual fields and a non-significant 10 millisecond LVF reaction time advantage. Post-hoc analysis employing two two-factor (Sex x VF) repeated measures ANOVAs for accuracy and reaction time failed to find significant differences.

Visual type effects. A significant visual type main effect for accuracy was found using the three factor mixed design ANOVA described above [$F(2/12) = 17.02$, $p < .0003$]. Overall accuracy scores reflect the following: semantic = 90.9 %, phonetic = 85.7 %, and facial = 66.6 %. Significant differences were found between semantic and facial accuracy scores [$t(7) = 4.8724$, $p < .002$] and between phonetic and facial accuracy scores [$t(7) = 2.9396$, $p < .03$] while no significant differences were found between semantic and phonetic stimuli. Grand mean reaction time scores indicate faster reaction times to the verbal stimuli (phonetic = 655 ms, semantic = 693 ms) than to the non-verbal stimuli (facial = 719 ms) although the differences did not reach statistical significance. Based upon lower accuracy scores (Figure 1) and longer reaction times (Figure 2) it is reasonable to infer that the facial stimuli were more difficult than either the semantic or phonetic stimuli.

FIGURE 1

**The Effects of Visual Type on Mean
Accuracy Scores in Experiment 1**

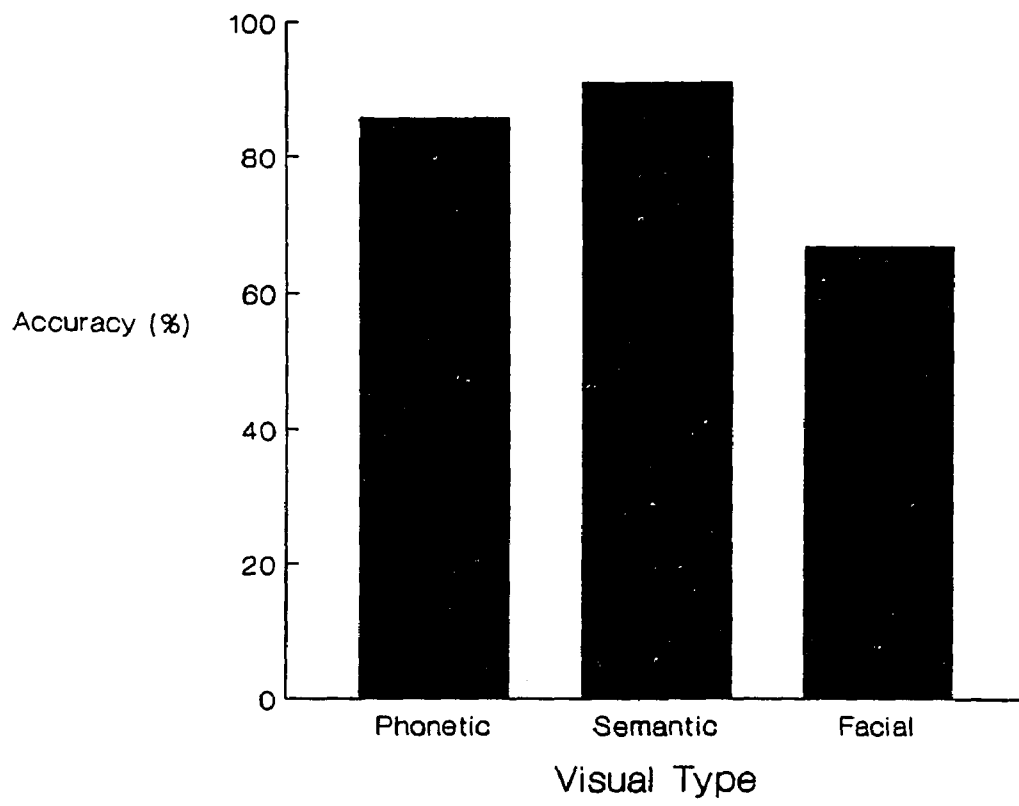
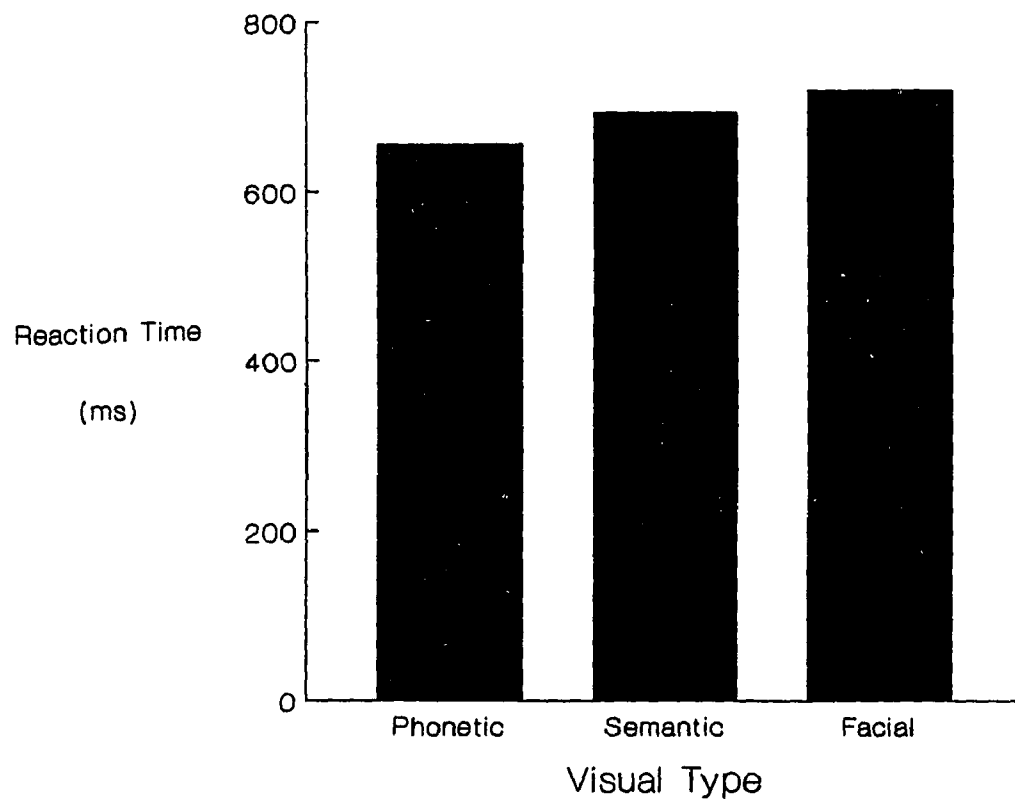


FIGURE 2

**Mean Reaction Time Scores for the
Three Types of Visual Stimuli in Experiment 1**



The visual accuracy scores obtained in Experiment 1 were then used as a baseline for the derivation of deviation scores in Experiment 2 (procedure described below).

Discussion

Numerous prior studies have indicated a consistent RVF advantage when verbal stimuli are displayed tachistoscopically (e.g. Lukatela, Carello, Savic, & Turvey, 1986). The present study has likewise demonstrated significant RVF advantages for verbal visual stimuli. The stimuli requiring semantic categorization were the most strongly lateralized to the RVF and so suggestive of left hemisphere processing. Phonetic visual stimuli, failed to show significant visual field differences for either reaction time or accuracy although results were in the expected direction. A post-hoc analysis did, however, determine that female subjects responded significantly faster with RVF presentations as compared to left while no significant VF difference was found for their male counterparts. This is somewhat surprising in that when significant differences are found in visual half-field studies it is more typically males who show greater visual field asymmetry (Levy & Reid, 1976). However, Bryden (1979) also found greater asymmetry in right-handed females than males. It is important to note that the number of subjects (4 males, 4 females) is small and so this result should be viewed cautiously.

The semantic and phonetic stimuli appear to be similar in difficulty to one another with responses to semantic stimuli being somewhat more accurate although

slower than responses to phonetic stimuli. In contrast, the responses to facial stimuli were both less accurate and slower to occur than for the verbal stimuli. Facial stimuli also failed to demonstrate a visual field advantage for either accuracy or reaction time, suggestive of neither a left nor right hemisphere processing advantage.

The research literature paints a confusing picture of visual field effects for faces, particularly as it relates to sex of the subject. Rizzolatti and Buchtel (1977) found a significant LVF reaction time advantage for males though not for females. Using accuracy as a dependent measure has yielded no sex differences (Piazza, 1980) while a study by Jones (1980) requiring subjects to classify photographs as either male or female revealed a RVF advantage for right-handed males and no VF difference for females. To further confuse the picture Ladavas, Umilta, and Ricci-Britti (1980) found a LVF reaction time advantage for females but not for males when the faces displayed emotion. Lastly, two recent studies have demonstrated a shift in VF advantage for women over the phases of their menstrual cycle. This shift has been shown to occur for facial stimuli (Heister, Landis, Regard, & Schroeder-Heister, 1989) and line orientation judgements (Chiarello, McMahon, & Schaefer, 1989) although neither study has indicated any VF shift for verbal stimuli.

The present study indicates that there were sex differences approaching significance for both accuracy and reaction time. Males demonstrated a non-significant LVF advantage for both dependent measures while females proved the reverse, showing a non-significant RVF advantage. If indeed this sex difference for facial stimuli were to carry over to the subjects in Experiment 2, then it would be expected that facial stimuli would have greater interference effects on female auditory performance while males would not be adversely effected by the dual-task (auditory and visual facial condition).

EXPERIMENT 2

With the baseline visual accuracy scores obtained in the preceding experiment, the visual task was then paired with the CV dichotic task in order to create the dual-task paradigm in Experiment 2.

Method

Subjects: Eighteen new subjects (nine males, nine females) participated in Experiment 2. These subjects were randomly assigned to the three different visual onset groups (0 ms, 460 ms, and 920 ms) with equal numbers of males and females in each visual onset group.

Apparatus: The auditory stimuli were presented on a Sony reel-to-reel stereo tape recorder (Model # TC270) and Lafayette stereo headphones (Model # SP-25) at 78 dB per channel.

The consonant-vowel syllable dichotic tape used in this study was prepared at the Haskins Laboratories (Connecticut). The tape contained six syllables (pa, ta, ka, ba, da, ga) which were produced by a female speaker and edited to a duration of 300 ms and aligned using the Pulse Code Modulation system at the Haskins Laboratories. The tape consisted of a practice block (16 trials) and four experimental blocks each containing 28 trials.

The tape was constructed so that on half the trials the probe item was the same as one of the items of the dichotic pair, with an equal likelihood of having left and right ear matches. The remaining half contained

probe items that were different from both dichotic stimuli.

Random pairing of a specific visual stimulus with an auditory trial was used until each visual condition had the proper number of trials for each auditory block and for each half of the session. As visual stimuli in a specific condition were depleted, randomization continued with visual stimuli from the remaining conditions. This approach was used to insure an equal number of trials in each condition.

Procedure: Eighteen subjects participated in two one hour sessions; one session per week for two consecutive weeks. The subjects in Experiment 2 were randomly assigned to three groups which were the three different visual exposure onset times (0 ms, 460 ms and 920 ms). A session was as follows: The subject was first given his/her semantic or phonetic category (these were presented by the principal investigator) and told to respond when he/she saw a "happy" face (a picture was shown of a "happy" face) or when the verbal stimuli met the category criteria. The subject was required to repeat his or her category or sound three times to assure that he/she had become familiar with it. The task was described to the subject (Appendix D). Each trial was made up of a 300 ms dichotic pair followed one second later by a binaural probe. Based upon the visual onset condition (VO), the

subject either received a 60 ms unilateral tachistoscopic presentation immediately following the offset of the dichotic pair (condition V01), 460 ms after the dichotic pair (condition V02), or 920 after the dichotic pair (condition V03). Half of the subjects were randomly chosen to receive the semantic/facial condition during the first session and the phonetic/facial condition during the second session while the other nine subjects received the reverse order (see Appendix E for experimental conditions). Each session was set up in one of two ways, as shown in Appendix F.

Baseline auditory scores (no visual presentation) were obtained at the beginning and end of the first experimental session (Sequence 1, Appendix F) and in the middle portion of the second session for half the subjects (Sequence 2, Appendix F). The reverse order was used for the remaining half of the subjects. Fifty-six auditory baseline trials were performed during each session for a total of 112 baseline trials for the two experimental sessions. In the middle of each testing session the headphones and both response keys were reversed in order to counterbalance the tasks.

Inter-trial intervals were set at six seconds. All raw data (subject responses) were placed on scoring sheets (Appendix G) by the principal investigator. The subject was instructed that the auditory task was the primary task. They were instructed to respond as to

whether the binaural probe matched one of the dichotic pair prior to responding to whether the visual presentation matched one of the visual criteria given at the beginning of the session.

At the conclusion of the study the purpose of the research was explained to the subject.

Data Analysis: Analysis of variance and analysis of covariance utilized BMDP-2V, correlation coefficients were generated using BMDP-6D and simple effects testing used BMDP-4V. Analyses were run on the VAX/VMS system of the University of New Hampshire.

Dunnett tests were performed using the procedure described by Keppel (1973). All t tests were executed using Ecstatic (copyright 1988), a microcomputer based statistical software package.

Statistical analysis of the data collected in Experiment 2 can be divided into 6 major components.

- 1) A repeated measures ANOVA (Sex x Ear) was used to examine the main effects and possible Sex x Ear interaction for reaction time and accuracy obtained during baseline auditory trials. T-tests were used to determine if an ear advantage existed for male and female subjects for either of the two dependent measures.
- 2) The second series of analyses were performed on the accuracy and reaction time data collected in the auditory task during the dual-task

conditions. Two five-factor mixed design analyses of covariances [VO x Sex x (VF x VT x Ear)] were employed. Accuracy scores and reaction time scores served as the dependent measures for these analyses. The accuracy and reaction time scores obtained during the baseline auditory portion of Experiment 2 served as the covariates in their respective analyses.

- 3) The accuracy scores collected in response to the visual stimuli were analyzed using a five factor mixed design analysis of variance [VO x Sex x (VF x VT x Ear)].
- 4) Deviation scores (Kingsberg, LaBarba, and Bowers, 1987) were obtained in order to view the variation from baseline performance for the auditory and visual tasks. A deviation score for each subject's accuracy data in each of the cells presented in Table 3 was obtained for the auditory task. The deviation score was calculated by subtracting each subject's left ear baseline score from each left ear visual field and visual type score (e.g. subject #1: left ear/ left visual field/ semantic score minus left ear baseline score equals the deviation score). The right ear baseline score was then subtracted from each of the right ear

TABLE 3
Experiment 2 Cell Means

		FEMALES					
		LEFT EAR			RIGHT EAR		
		0ms					
		SEM	PHO	FACIAL	SEM	PHO	FACIAL
LVF		75.9 1096	72.2 1202	70.4 1104	90.7 977	74.0 968	77.8 899
		92.5 -4.3	81.5 -19.0	70.0 -1.7	81.0 -5.7	66.7 -36.6	66.7 15.9
RVF		71.7 1033	63.3 1069	77.8 1148	86.7 1002	71.7 1029	88.9 1005
		92.6 -13.9	70.4 -40.4	87.5 20.6	96.2 0	77.8 -29.3	66.7 6.1
460ms							
LVF		61.1 1148	66.7 1057	70.4 933	66.7 1122	62.9 977	70.3 1012
		92.5 0	74.1 -12.8	63.3 10.7	81.5 -18.6	66.7 -37.0	53.3 13.2
RVF		53.7 1222	75.0 1117	79.0 1079	55.0 1069	66.7 1102	77.8 1096
		88.9 -16.5	66.7 -13.3	81.5 34.9	92.5 -24.6	74.1 -27.3	66.7 -5.8
920ms							
LVF		87.0 1219	81.2 1153	72.2 1186	83.3 1132	75.9 1112	73.1 1225
		92.5 11.6	81.5 -5.2	80.0 14.9	92.6 9.1	74.1 -16.7	80.0 13.5
RVF		80.0 1285	70.0 1159	77.8 1114	75.0 1199	63.3 1119	79.6 1219
		92.6 -.08	66.6 -32.6	79.1 17.1	92.5 -4.6	81.4 -23.4	70.8 11.7
		MALES					
		LEFT EAR			RIGHT EAR		
		0ms					
		SEM	PHO	FACIAL	SEM	PHO	FACIAL
LVF		72.2 1016	68.5 1250	85.2 1102	71.6 1147	63.0 1186	75.3 968
		81.5 -8.7	74.1 -11.5	66.7 3.9	92.5 1.7	85.2 -6.0	86.7 4.0
RVF		61.7 1230	60.0 1294	72.2 1161	63.3 979	61.7 1114	75.9 1045
		92.5 -10.8	74.1 -22.2	75.0 1.0	96.2 -5.4	88.9 -5.8	79.6 9.3
460ms							
LVF		64.8 1345	61.1 1562	74.1 1242	81.0 1178	74.1 1202	85.2 1012
		88.9 -1.6	77.8 -8.1	40.0 -26.7	85.2 -12.9	85.2 -11.5	70.0 -2.7
RVF		76.6 1389	61.7 1602	71.8 1293	83.3 1235	88.3 1406	85.2 1159
		88.8 7.6	77.8 -9.7	75.0 7.7	88.9 -9.5	81.5 -3.1	70.8 -6.9
920ms							
LVF		74.1 906	50.0 870	70.4 883	88.9 880	70.4 813	88.9 881
		74.1 2.4	77.8 -9.7	73.3 12.4	88.9 8.1	74.1 -16.8	66.7 6.3
RVF		68.3 935	56.7 891	72.2 914	73.3 899	71.7 879	79.6 849
		85.2 5.1	96.2 13.2	70.8 13.5	88.9 -9.9	70.4 -21.4	87.5 13.7

Auditory Accuracy	Auditory Reaction Time
Visual Accuracy	Total Deviation Score / Subject

LVF = Left Visual Field
RVF = Right Visual Field

SEM = Semantic
PHO = Phonetic

conditions to create the right ear deviation scores. Visual deviation scores for each of the corresponding conditions described above were derived using the data obtained from Experiment 1 to serve as the baseline adjustment. The grand mean for the four male subjects for each of the six cells in Experiment 1 (See Table 2) served as the baseline visual control for the male subjects in Experiment 2 (e.g. the mean of the LVF semantic condition from Experiment 1 was subtracted from the left and right ear LVF semantic visual scores from Experiment 2). The identical process occurred for the female subjects in Experiment 2 although utilizing the grand means for the four female subjects in Experiment 1 as the baseline visual control. A total deviation score for the auditory/visual dual task was generated by adding the auditory deviation score to the visual deviation score. A five factor mixed design analysis of variance [VO x Sex x (VF x VT x Ear)] was then run using the total deviation scores as the dependent measure.

- 5) Correlational analyses were performed on visual and auditory accuracy for each of the VO x Ear x VF x VT conditions.

- 6) Planned comparisons were performed using Dunnett tests to compare the baseline auditory conditions (LE and RE) to the corresponding Ear x VF x VT conditions.

Results

In general, the results from Experiment 2 support many of the initial predictions. The CV dichotic tape utilized within the study demonstrated the expected RE advantage under baseline conditions and when combined with the phonetic visual task from Experiment 1 exhibited significantly greater levels of interference than for either the semantic or facial visual stimuli (Figure 4). Visual field of presentation impacted directly on speed of auditory processing with RVF presentations slowing reaction time relative to LVF presentations (Figure 3). Altering visual onset times failed to produce significant findings although trends in support of a multiple resource hypothesis were evident.

Ear advantage during baseline. When collapsed across sex ($N = 18$) significant ear differences were revealed for accuracy [$F(1/16) = 7.0684$, $p < .02$; RE = 81.4%, LE = 70.7 %] and a non-significant RE reaction time advantage was displayed (RE = 845ms, LE = 884ms). The Sex x Ear interaction was non-significant for both accuracy and reaction time. Post-hoc analysis revealed that female subjects displayed a significant RE advantage for reaction time [$t(8) = 3.2038$, $p < .02$; RE = 862ms, LE = 931ms] and a non-significant RE advantage for accuracy (RE = 82.2 %, LE = 76.6 %). Males demonstrated a very small non-significant RE reaction time advantage (RE = 828ms, LE = 839ms) while accuracy scores approached

significance [$t(8) = 2.2671$, $p > .054$; RE = 80.6 %, LE = 64.7 %].

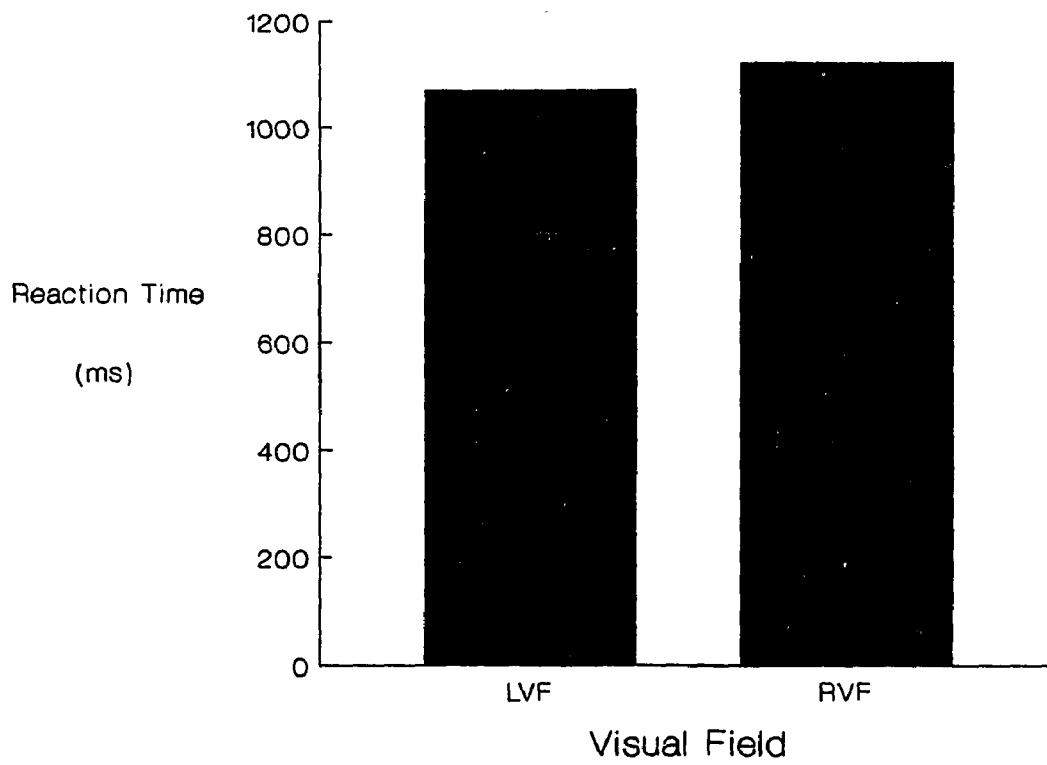
Effects of visual field on auditory processing.

When LVF presentations were combined with the dichotic task, a 38ms reaction time advantage in the auditory task occurred relative to RVF presentations (Figure 3). The ANCOVA performed on the reaction time scores demonstrated a significant main effect for visual field [$F(1/12) = 6.00$, $p < .04$]. Higher order interactions were present, however.

Effects of visual type on auditory processing. A significant main effect for visual type was evident from the ANCOVA [$F(2/24) = 10.43$, $p = .0005$] for the accuracy measure. Figure 4 indicates that the processing of phonetic visual stimuli interferes with the performance of the dichotic task to a greater extent than does the processing of both the semantic stimuli [$t(17) = 2.3074$, $p < .04$] and facial stimuli [$t(17) = 5.0106$, $p < .0001$]. Performance during the presentation of facial visual stimuli (77.1 %) resulted not in interference with auditory processing but rather a slight non-significant facilitation of auditory processing above baseline (76.0 %). In contrast, phonetic stimuli resulted in a significant decrease in auditory accuracy when compared to baseline auditory performance [$t(17) = 3.2198$, $p < .005$]. Significant higher order interactions were also present.

FIGURE 3

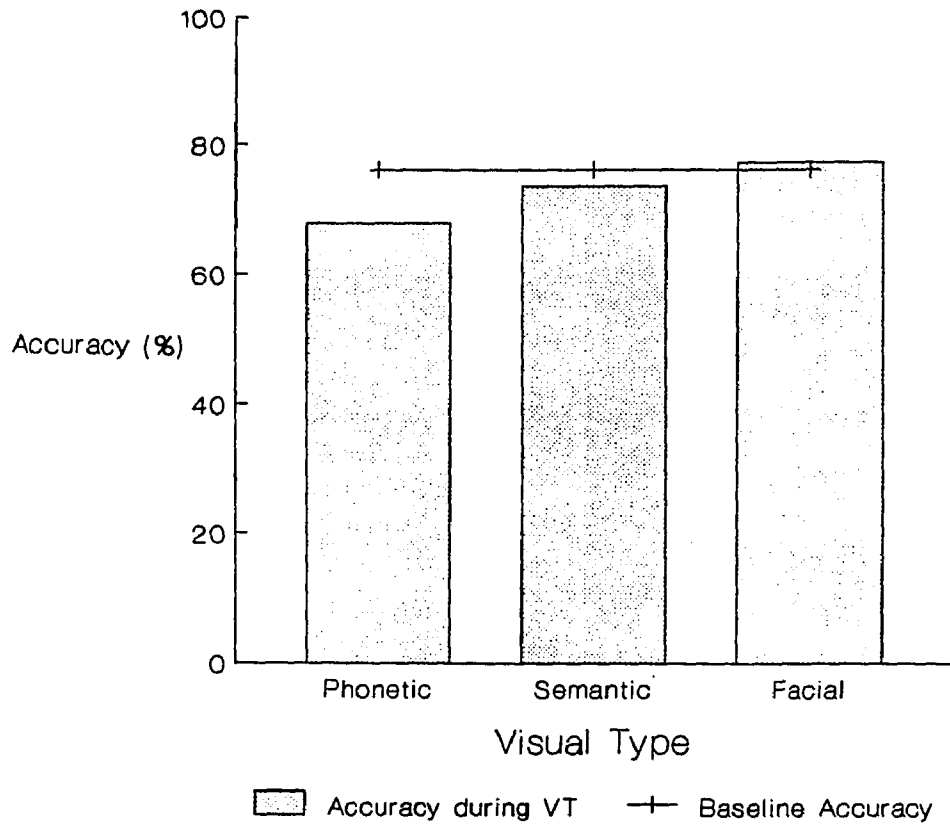
The Effects of Visual Field on Mean
Reaction Time to the Auditory Task



* Experiment 2

FIGURE 4

**The Effects of Visual Type on
Mean Auditory Accuracy**



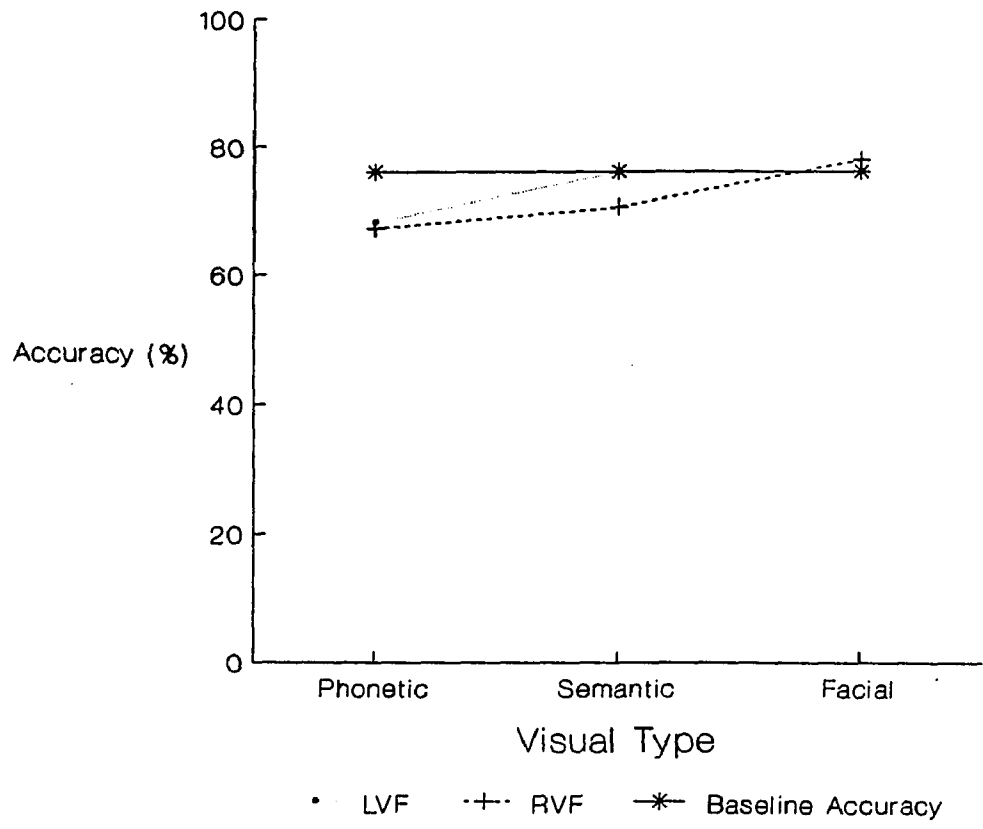
* Experiment 2

Interaction effects. A significant VF x VT interaction for accuracy [$F(2/24) = 3.68, p < .05$] revealed greater interference with auditory processing from RVF phonetic and semantic presentations than from the same stimuli presented in the LVF (Figure 5) while performance on LVF faces was below that demonstrated for RVF faces. Left visual field semantic and facial presentations had neither an interfering nor facilitative effect on auditory processing with performance collapsed across sex at an accuracy level equivalent to that obtained under baseline conditions. A second significant interaction, Sex x VF x VT [$F(2/24) = 5.12, p < .02$] as shown in Figure 6, reveals drastically different performance by males and females. Increases above baseline are noted for males for both left and right visual fields when paired with the facial stimuli and LVF semantic presentations. Female performance, however, was at or below baseline for all VF and VT conditions. It is interesting to note that baseline performance was more accurate for the female subjects (79.4 %) than for the male subjects (72.6 %). When collapsed across all dual-task conditions, overall accuracy for females was at 73.5 % while for males it was 72.3 %.

In an attempt to better understand both the VF x VT and Sex x VF x VT interactions, simple effects testing was undertaken using BMDP-4V. The first level of simple effects testing (Keppel, 1973) revealed the following

FIGURE 5

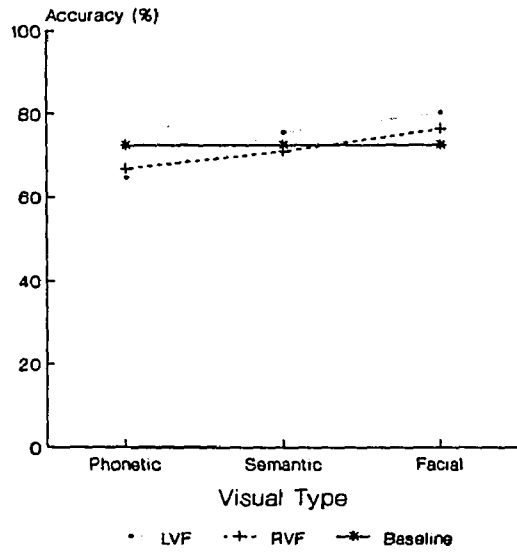
**Mean Auditory Accuracy During Left
or Right Visual Field Presentation
of Phonetic, Semantic, or Facial Visual Stimuli**



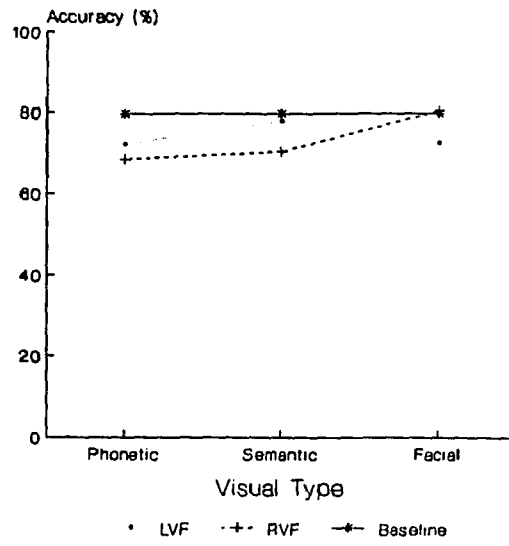
* Experiment 2

FIGURE 6

**The Effect of Gender, Visual Field,
and Visual Type on Mean Auditory Accuracy**



• Male



• Female

significant interactions:

Sex x VT at LVF [F(2/24)=4.41, p<.03]

Sex x VF at Facial [F(1/12)=11.24, p<.006]

VF x Semantic [F(1/12)=7.61, p<.02]

VT x LVF [F(2/24)=6.38, p<.006]

VT x RVF [F(2/24)=10.16, p<.0006]

To further examine these simple effects, simple simple effects testing (Keppel, 1973) was performed by running the analyses first using only male subjects followed by the same analysis using only female subjects. The simple effects procedure within BMDP-4V does not permit a between factor (e.g. Sex) to be held at each of its levels (e.g. males, females) without introducing the second between factor (VO). Executing the program with only the male or female subjects allows the examination of the simple simple effects at each level of the between factor, Sex.

Female subjects on simple simple effects testing demonstrated a Field effect for Semantic condition [F(1/8)=7.66, p<.03] and a Field effect for Facial condition [F(1/8)=15.09, p<.005]. As can also be seen in Figure 6, these results represent significant differences on auditory accuracy between LVF and RVF presentations for both the semantic and facial stimuli. In addition, they appear to explain the Sex x VF x Facial and VF x Semantic interactions found during simple effects testing as males did not display significant effects on similar

comparisons.

Males demonstrated both a significant VT effect for LVF [$F(2/16)=12.02$, $p<.0007$] and a VT effect for RVF [$F(2/16)=5.87$, $p<.02$] and so required further testing to determine the source of the interactions. It should be noted that due to the number of comparisons being made, the risk of committing a Type I error has increased and significance levels greater than .01 should be viewed cautiously. Simple simple effects testing revealed the following significant results leading to the interactions above:

RVF-F x RVF-P [$F(1/8)=10.27$, $p<.02$]

RVF-S x RVF-P [$F(1/8)=6.78$, $p<.04$]

LVF F x LVF-P [$F(1/8)=22.49$, $p<.002$]

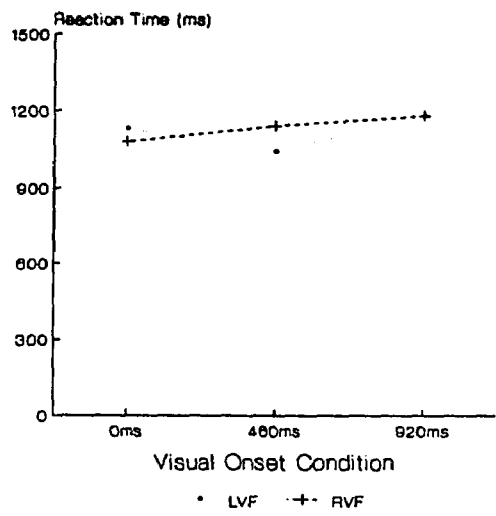
LVF S x LVF-P [$F(1/8)=11.19$, $p<.01$]

Phonetic stimuli, as expected, proved to cause significantly more interference with auditory processing than either semantic or facial stimuli.

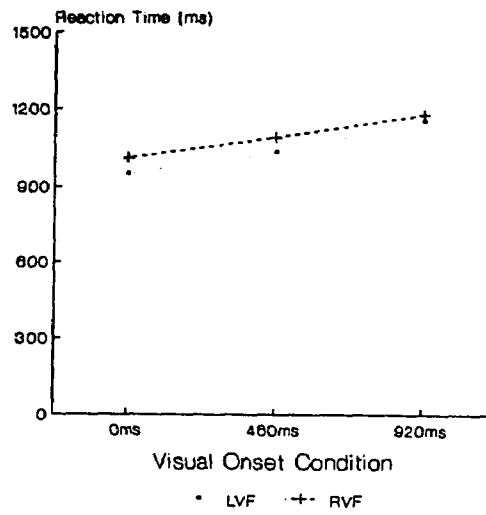
Figure 7 represents a significant four-way interaction of VO x Sex x Ear x VF [$F(2/12) = 5.10$, $p < .03$]. Where Figure 7 presents this interaction showing treatment means, Figure 8 presents the interaction as a deviation score derived by subtracting the baseline reaction time from the treatment means. It is clear from a comparison of the two sets of graphs that the males in the 920 ms VO condition responded more rapidly than their counterparts in the 0 ms or 460 ms

FIGURE 7

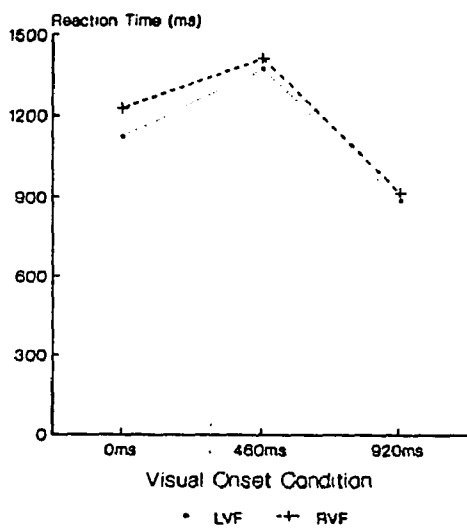
**The Effect of Visual Onset Condition,
Gender, Ear of CV Presentation, and
Visual Field on Mean Reaction Time**



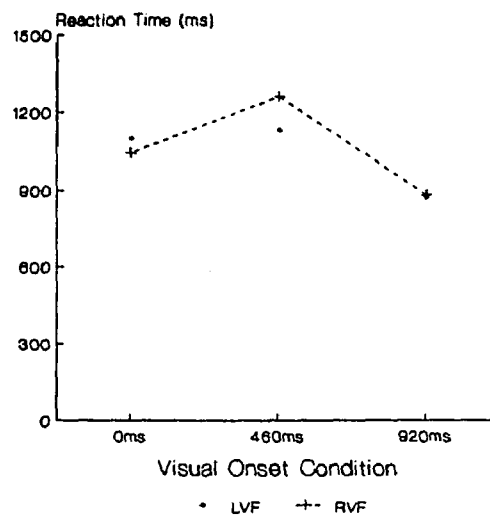
• LE - Female



• RE - Female



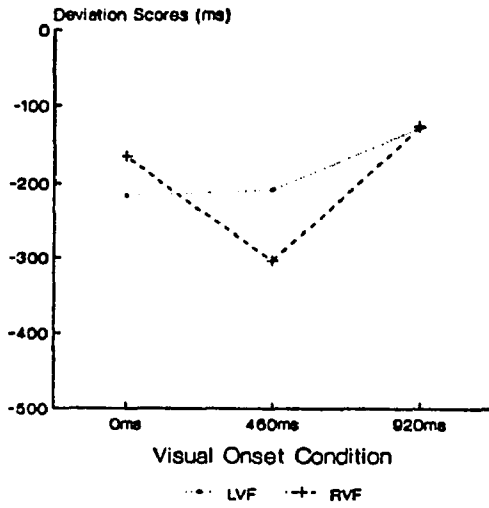
• LE - Male



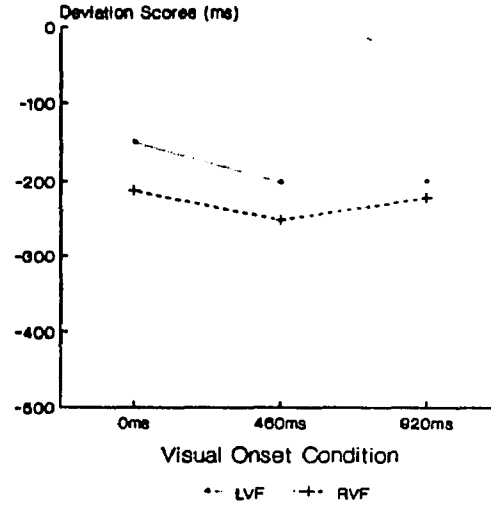
• RE - Male

FIGURE 8

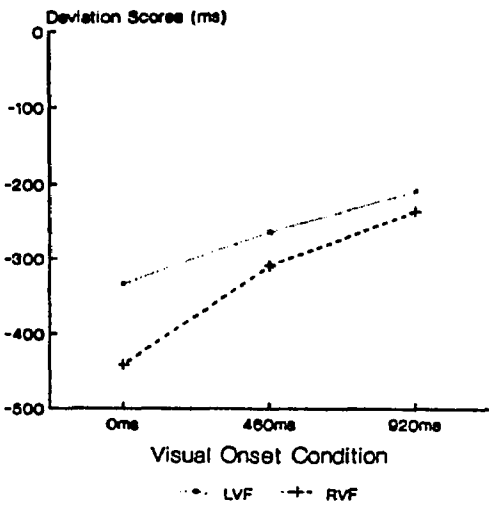
**The Effect of Visual Onset Condition,
Gender, Ear of CV Presentation, and
Visual Field on Mean Deviation Scores**



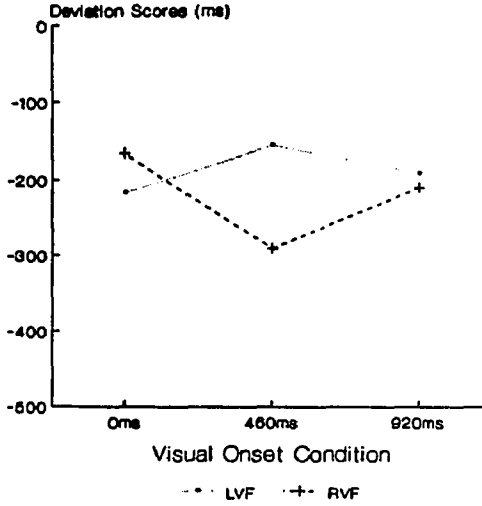
• LE - Female



• RE - Female



• LE - Male



• RE - Male

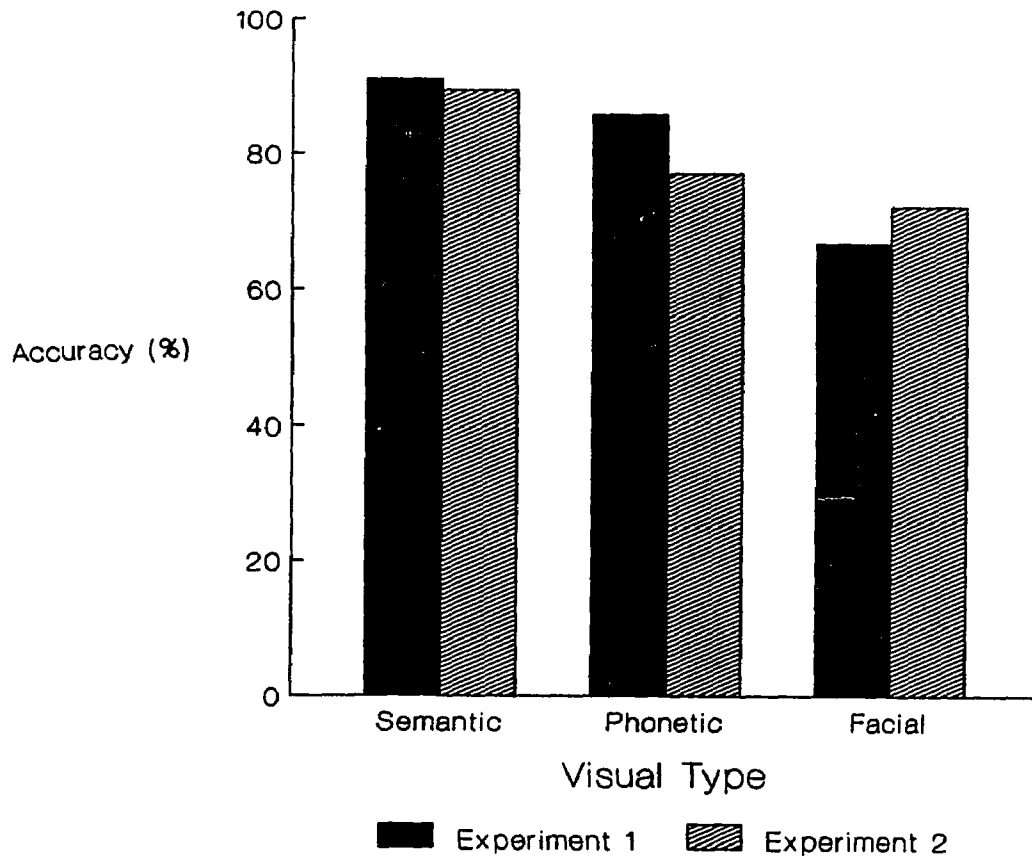
conditions. However when deviation scores are derived, the reaction time differences between conditions decrease. As the N within each cell was equal to 3, the validity of this interaction is highly questionable. In addition, the interpretation of such a four-way interaction would be extremely difficult. This interaction was not predicted and so for this reason and those reasons above the interaction will not be considered further.

Effects of dual-task performance on visual processing. As with the visual type data obtained in Experiment 1, a significant main effect for visual type was revealed [$F(2/24) = 11.88, p = .0003$]. Figure 9 compares visual type accuracy in Experiment 1 and in Experiment 2. As expected, the dual-task had little impact on the processing of the semantic visual material but interfered with phonetic visual stimuli. The accuracy to facial stimuli actually improved under the dual-task condition with performance in Experiment 1 being at 66.6 % as compared to 71.9 % in Experiment 2.

An unexpected interaction was present during this analysis; Sex x Ear was determined to be significant [$F(1/12) = 6.32, p < .03$]. What this analysis represents is the accuracy of processing the visual stimuli during a right or left ear trial. It is important to note that a trial involves a dichotic pair, a visual presentation (0 ms, 460 ms, or 920 ms following the dichotic pair), and a

FIGURE 9

**Mean Visual Accuracy for Semantic, Phonetic, and
Facial Stimuli for Experiment 1 and Experiment 2**



binaural probe. The trial becomes a left ear or right ear trial at the time of the binaural probe which follows the visual presentation. This interaction is represented in Figure 10.

Dual-task processing. A major interest of this study was to view the effects of a dual-task on total available resources. This was best performed through the generation of deviation scores for both the auditory and visual tasks as deviation scores are indicative of the difference between single and dual-task performance. When these deviation scores are then combined, the resulting total is reflective of mean increases or decreases in total accuracy per subject for each condition across the dual task (Table 3).

A five factor mixed design ANOVA performed on these deviation scores revealed a significant main effect for visual type [$F(2/24) = 15.41, p < .0001$]. Figure 11 represents the total change in performance accuracy per subject as a result of visual type. As expected, combining the CV dichotic task with its phonological requirements, and the phonetic visual stimuli produced the largest interference effect. Figure 12 separates out the deviation from baseline into its auditory and visual task components. For both phonetic and semantic conditions the dual-task effects, auditory effects on visual processing and visual effects on auditory processing, appear to be uniform. However, as Table 4

FIGURE 10

**The Effect of Gender and Ear of CV Presentation
on Visual Accuracy During Experiment 2**

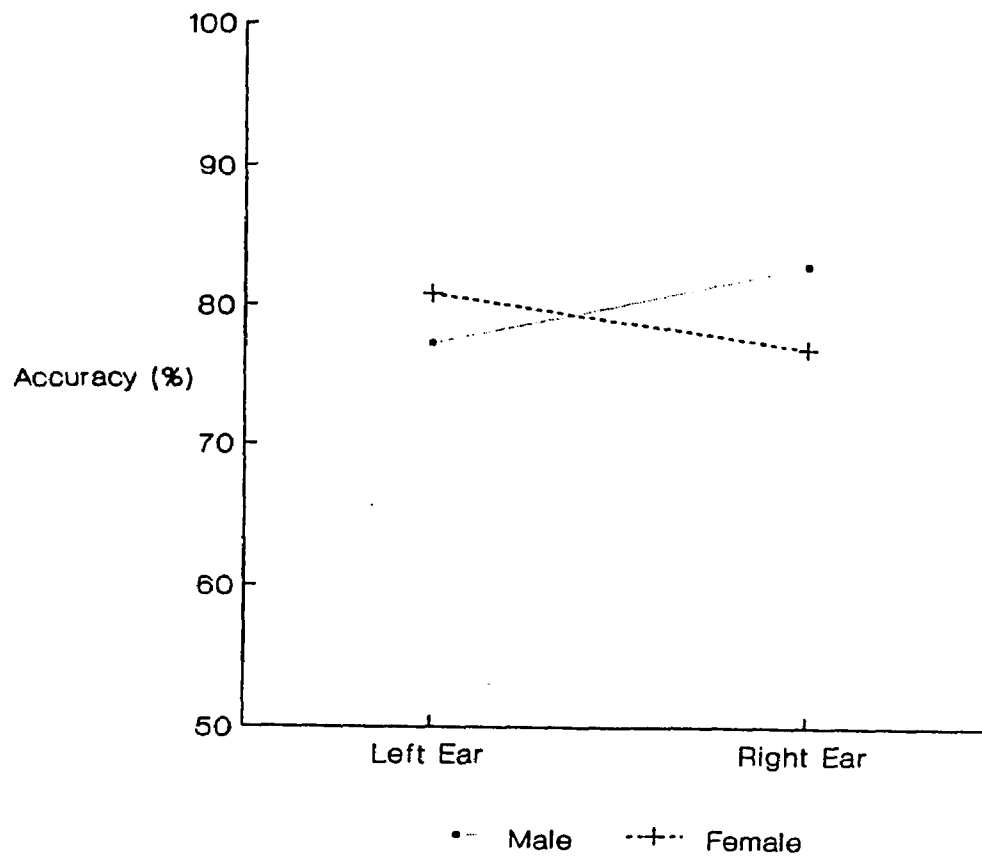


FIGURE 11

**Total Deviation Scores per Subject for the Three
Types of Visual Stimuli During the Dual-Task**

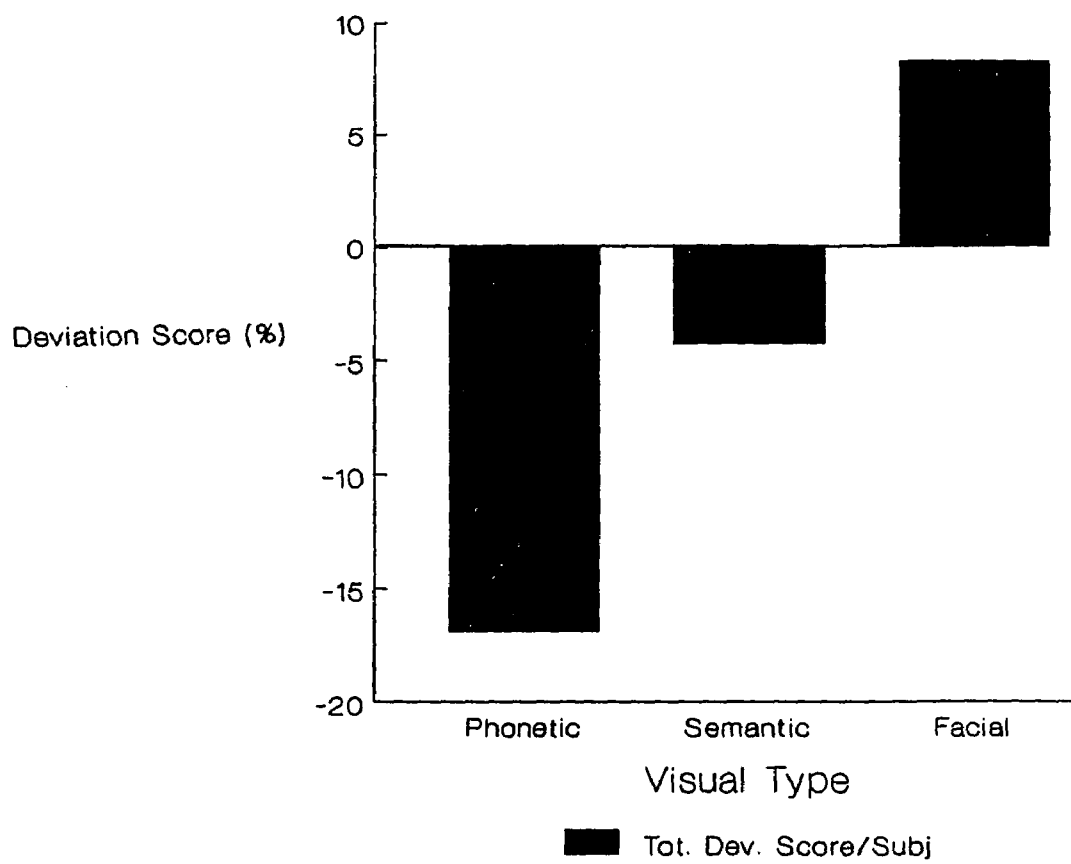


FIGURE 12

The Effect of Semantic, Phonetic, and Facial Visual
Stimuli on Deviation Scores for the Auditory and
Visual Tasks

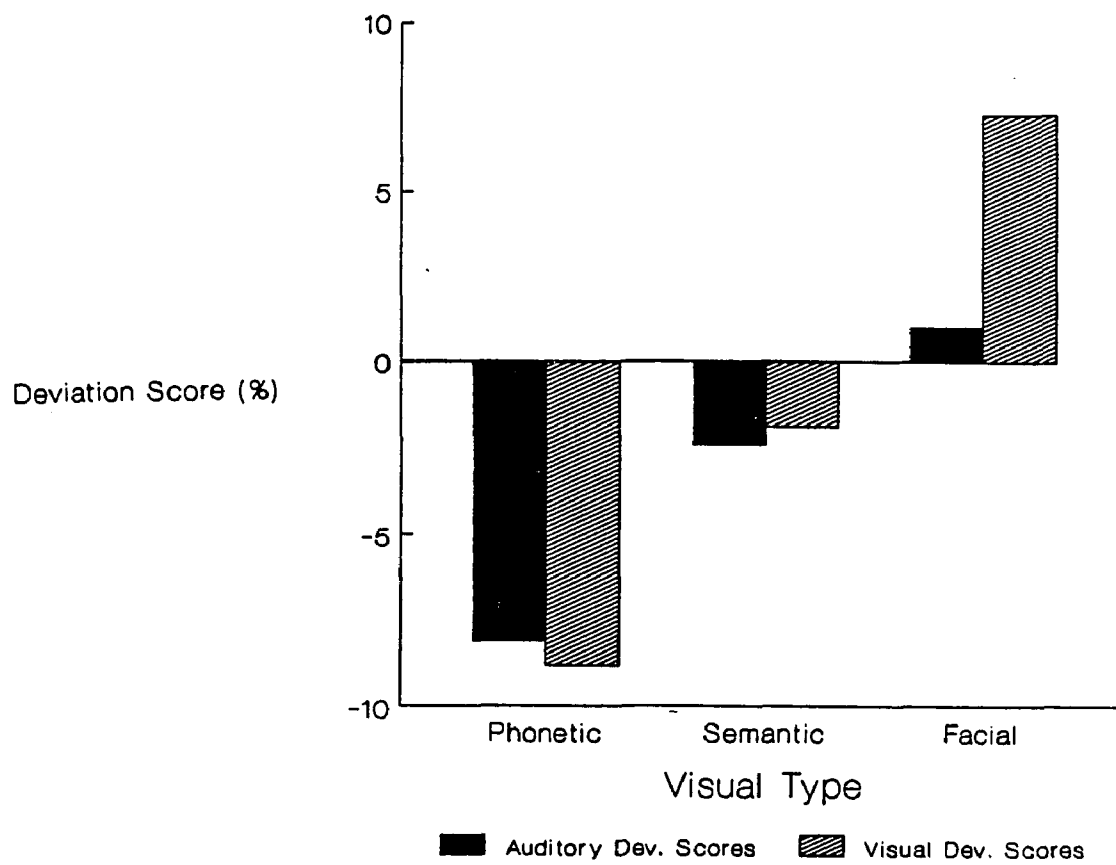


TABLE 4
Correlation Coefficients Between Auditory and Visual
Accuracy Measures Across Sex

		LEFT EAR			RIGHT EAR		
		SEM	PHO	FACIAL	SEM	PHO	FACIAL
0ms							
LVF		-.328	-.394	-.105	-.334	.212	-.088
RVF		.439	-.132	-.246	-.325	.438	-.098
460ms							
LVF		.609	-.231	.492	.673	-.183	.405
RVF		.463	-.447	.490	-.684	-.284	.798
920ms							
LVF		.531	.382	-.378	-.613	.393	-.237
RVF		.637	.082	.203	-.147	.553	.667

LVF = Left Visual Field

RVF = Right Visual Field

SEM = Semantic

PHO = Phonetic

indicates, in general, the correlation coefficients between auditory and visual accuracy scores performed across sex on the VO x Ear x VF x VT cells were very low, indicating a great deal of within subject variability throughout the study. All correlation coefficients were non-significant.

Two final interactions were determined to be significant using this five factor ANOVA. The Sex x VT interaction [$F(2/24) = 4.01, p < .04$] is represented in Figure 13 while the VF x VT interaction [$F(2/24) = 7.14, p < .004$] is shown in Figure 14. Males demonstrated less variability in terms of total deviation scores on the 3 visual stimuli (phonetic = -7.6, semantic = -2.8, and facial = 2.95) as compared to females (phonetic = -24.5, semantic = -5.69, and facial = 13.56). It is important to note, as shown in Table 2, that the female subjects in Experiment 1 averaged 58.8 % on facial presentations while males averaged 74.5 %. As Experiment 1 served as the baseline for the visual deviation scores, a very low baseline score might skew the results toward indicating a greater facilitation effect. Figure 12 depicts a much larger facilitation effect for the visual task in the facial condition than for the auditory task. This appears to result from extremely low mean facial accuracy scores in Experiment 1 for two of the four female subjects. These two subjects averaged only 46.6% correct while the other two females had a mean of 71% and the 4

FIGURE 13

The Effect of Gender and Visual Type on Mean Total
Deviation Scores per Subject

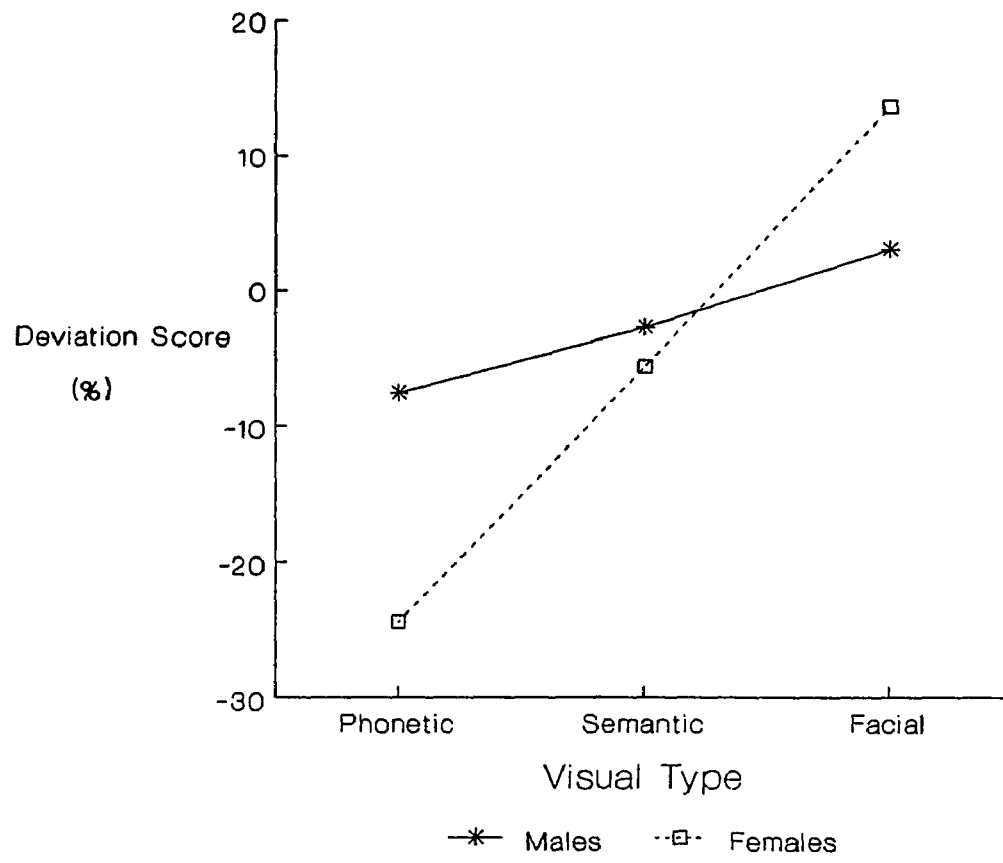
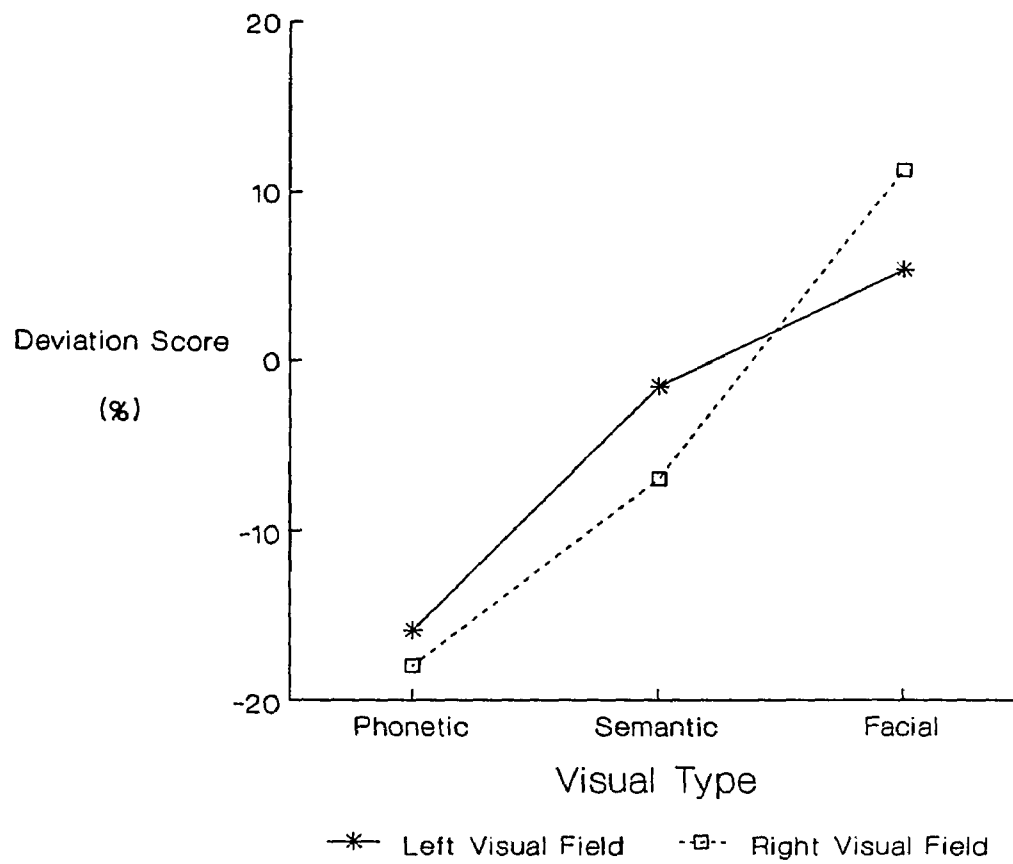


FIGURE 14

**The Effect of Visual Field and Visual Type on
Mean Total Deviation Scores per Subject**



males had a mean of 74.5%. The females in Experiment 2 had a visual accuracy score for facial stimuli of 72.1%. Given the overall low facial accuracy score from Experiment 1, the visual deviation score appears to skew the results towards appearing as if there is a greater effect than actually is present. Post-hoc simple effects testing on the combined deviation scores for females showed the RVF-Facial condition to be significantly different than both the RVF-Semantic [$F(1/8) = 13.38, p < .007$] and RVF-Phonetic [$F(1/8) = 36.43, p < .0003$] conditions. The LVF-Facial condition was also significantly different from the LVF-Phonetic condition [$F(1/8) = 19.15, p < .003$]. Males showed no Type x VF interactions. As can be seen in Figure 12, the component deviation scores for the auditory and visual tasks are very similar for both the semantic and phonetic conditions. In contrast, the auditory and visual component deviations for facial are highly discrepant. If the two female subjects in Experiment 1 with a mean of 71% are used as the baseline adjustment, then the auditory/visual deviation scores would be virtually identical as exists for both the phonetic and semantic conditions.

This last interaction (VF x VT) indicates that greater interference occurs with verbal visual stimuli presented into the RVF. This is suggestive of a processing mechanism continuum with less interference

occurring when fewer similar mechanisms are employed. Right visual field-phonetic trials are assumed to maximally share processing mechanisms with the CV dichotic task based on what appears to be a strong LH processing advantage for both the auditory and visual tasks. The overall auditory baseline indicates a RE accuracy (RE = 81.4 %, LE = 70.7 %) and reaction time (RE = 845 ms, LE = 884 ms) advantage while visual phonetic stimuli also displayed a right hemispace advantage for accuracy (RVF = 86.6 %, LVF = 84.8 %) and reaction time (RVF = 623 ms, LVF = 686 ms). This advantage from left hemispheric mechanisms and the commonality of phonological analysis at a task level appears to lead to greater interference.

To further examine the cause of the Sex x VT and VF x VT interactions simple effects testing followed by simple simple effects testing was undertaken. In addition to the above interactions simple effects testing revealed a VT x RVF interaction [$F(2/24) = 16.04, p < .0001$].

Simple simple effects testing was then carried out on the males and females separately to allow for the between factor, sex, to be held at each level (i.e. male, female). No significant effects were found for males. Females demonstrated the following results:

VT x LVF [$F(2/16) = 11.57, p < .0008$]

VT x RVF [$F(2/16) = 15.57, p < .0002$]

VF x Semantic [$F(1/8) = 10.86, p < .02$].

Baseline to treatment comparisons. Dunnett tests were performed using LE and RE baseline trials as the control group and VF x VT conditions (LVF - Phonetic, LVF - Semantic, LVF - Facial, RVF - Phonetic, RVF - Semantic, RVF - Facial) as the experimental groups. A total of six two-tailed Dunnett tests were performed with the alpha level set at .05. No significant interference or facilitation effects were found for any of the comparisons.

Discussion

The CV dichotic listening procedure used in this study has in past research (Springer, et al., 1978; Spielman, 1979) yielded significant ear effects. The present study reports findings similar to these previous studies with a strong RE advantage being evident. It has frequently been proposed that these obtained RE advantages are indicative of left hemisphere language lateralization (Beaton, 1985; Springer & Deutsch, 1985) although these behavioral indices do not always seem to correlate well with clinical findings (Blumstein, Goodglass, & Tartter, 1975; Channon, Shugens, Daum, & Polkey, 1990). As Springer and Deutsch (1985) note, sodium amobarbital testing at Montreal Neurological Institute found greater than 95 % of the right-handers to have speech localized to the left hemisphere. However, a dichotic listening study using CV syllables has found RE advantages in 71 % of its all right-handed subject sample (Sidtis, 1982). The present study determined that 78 % of the subjects displayed a RE accuracy advantage although only 50 % of the subjects demonstrated a RE advantage for both reaction time and accuracy. Sidtis (1982) has proposed that the difference between the behavioral measures (e.g. dichotic listening) and actual clinical findings is due, in part, to intersubject variability in ascending auditory projections. Many of the assumptions regarding dichotic listening stem from a

theoretical model proposed by Kimura (1961), that input from contralateral pathways suppresses input through an ipsilateral route. Sidtis (1982) suggests that these contralateral auditory projections are not always superior to ipsilateral auditory projections and that left hemisphere language lateralization does not presume contralateral pathway superiority that would support behavioral indices of lateralization.

The implications of the above findings for this study are: 1) The lack of a RE advantage or the demonstration of a LE advantage for the dichotic task does not indicate bilateral or RH language lateralization and that for the purpose of this study, LH language is assumed to occur in the vast majority of the subjects; and 2) Intersubject variability may be considerable as a result of these subcortical asymmetries. Conditions with small N's would be expected to be more affected by this intersubject variability and so greater emphasis throughout this study will be placed on conditions where larger subject samples exist.

If indeed the assumption is made that a CV dichotic task requires the processing mechanisms and resources of the LH in this right-handed sample then a visual stimulus projected tachistoscopically into the RVF, also potentially accessing similar mechanisms, may be expected to slow auditory processing relative to LVF presentations. This is in fact what was found. Auditory

processing during RVF presentations was 38ms slower than during LVF presentations even given an overall 50ms RVF advantage in Experiment 1. Two possible explanations can be suggested.

If as Heilman and his colleagues propose (Heilman & Van Den Abell, 1979; Bowers & Heilman, 1980) LVF-RH trials serve to activate the LH more than RVF-LH activates the RH and even the LH, then this increased activation from LVF trials may result in faster processing of the auditory task. This does not fully explain the results given two factors: 1) Bowers and Heilman (1980) found that their obtained activation effects occurred under material-specific conditions with words and faces causing LH and RH activation, respectively; and 2) In the present study two thirds of the visual stimuli were verbal in nature with a RVF-LH advantage occurring under single task conditions and with the remaining one third (i.e. facial stimuli) demonstrating an absence of a visual field advantage. It would be expected, based on these factors, that greater levels of activation of the LH from RVF trials would have resulted if the effects were merely due to activation alone. Where Bower's and Heilman's (1980) work utilized a very simple reaction time paradigm, the processing requirements of the present study were more demanding and so do not appear to fit fully into the activation model proposed by Bowers and Heilman (1980).

Alternatively, from the processing matrix proposed by Wickens (1984) this observed interference would arise from shared central processing and not as a result of shared encoding which, in the Wickens' (1984) model, is proposed to be separate for visual and auditory modalities. However, the relationship between modality and stage of processing may not be as simple as proposed. If, as discussed above, the majority of the visual stimuli (semantic and phonetic) require LH mechanisms while the facial stimuli require RH mechanisms, then ultimately LVF and RVF verbal presentations will eventually utilize the same processing mechanisms, those of the LH. With the LH occupied by the CV dichotic stimuli, then the introduction of visual stimuli could potentially deplete available resources or compete for similar processing mechanisms. Based on the results obtained, it appears that the RVF presentations are competing for early stage processing mechanisms and resources (Moscovitch & Klein, 1980) in the LH while these same stimuli initially delivered to the LVF-RH receive early stage analysis in the RH (Friedman & Polson, 1981) prior to transfer across the callosum for later stage analysis and response determination. Shiffrin and Schneider (1977) suggest that these early stage mechanisms would be considered automatic and so be expected to operate in parallel with one another without decrement, except in cases where simultaneous

target stimuli are present.

In the present study all verbal stimuli would appear as targets until later stage categorical processing occurs and so RVF trials may be drawing this attentional response as described by Shiffrin and Schneider (1977). It is this proposed sharing of resources in the LH that causes the response delay relative to LVF presentations. It is important to note that there was an overall increase in reaction time to the auditory task from the single to dual-task conditions of 226 ms; a 207 ms increase for LVF presentations versus a 245 ms increase for RVF presentations. If indeed verbal visual presentations require LH mechanisms and facial stimuli can be processed equally well in both hemispheres and one considers the Friedman and Polson (1981) proposal that a task's resource composition can be flexible then it would be expected that LVF facial stimuli would slow auditory processing the least of any visual field/visual type (VF/VT) combination. This is exactly what occurred. As Table 3 indicates, LVF facial trials delay auditory reaction time by only 165ms relative to baseline, 54ms less than any other VF/VT combination. As Navon and Gopher (1979) have suggested, a concurrence cost could result from the organizing, coordinating, scheduling, and allocation of resources and not necessarily from a sharing of mechanisms. In this case, the cost could result from the preparation and planning involved in a

second response (i.e. the response to the visual stimuli) and so it might be suggested that facial stimuli, when presented in the LVF, do little to impede the CV dichotic task.

Auditory processing was influenced not only by alterations in visual field but rather the type of visual material presented also significantly influenced the accuracy of auditory processing. Figure 4 indicates, as the degree of similarity to the auditory task decreases along the continuum (phonetic, semantic, facial), the interference effects also decrease relative to baseline. With phonetic visual stimuli joined with the CV dichotic task in the dual-task condition, accuracy in response to the CV task declines presumably because of the increased utilization of similar processing mechanisms (Friedman, Polson, Dafoe, & Gaskill, 1982; Wickens, 1984). In addition, reaction time to the auditory task was longest when phonetic stimuli were presented into the RVF when compared to the other VF/VT combinations. When dissimilar mechanisms are used, as with the CV/facial visual dual-task no interference was observed but rather a small non-significant facilitation effect was noted. This result lends further support to the suggestion above that facial stimuli are processed independently of the auditory task, probably in the RH. The significance of this finding becomes more interesting when the results from Experiment 1 are considered. Under the single task

condition in Experiment 1, the facial stimuli were found to be more difficult than either the semantic or phonetic stimuli yet the facial stimuli had a small facilitation effect on the auditory task. Shiffrin and Schneider (1977) have suggested that increases in load in a dual-task result in decreased performance. The results of the present study do not support this suggestion but rather indicate that dual-task performance will be dependent upon the resource composition required by each stimulus and that the degree of difficulty under single task conditions may not predict dual-task results. As Kinsbourne and Hiscock (1983) state "if heavier demands of the dual-task situation cause an increase in arousal and thus in available resources, performance in the dual-task condition might equal or even surpass that in the single task condition" (page 320). A recent study by Banich and Belger (1990) also found that under conditions of high task demand, interhemispheric interaction resulted in improved performance.

For auditory accuracy a significant VF x VT interaction developed (Figure 5). As with reaction time, the verbal stimuli cause less interference with auditory processing when presented in the LVF. In contrast, facial stimuli appears to have less of a detrimental and even a facilitative effect when presented in the RVF. This effect is more easily explained when the significant Sex x VF x VT interaction is considered. Some

differences between males and females appear to exist in this subject sample, particularly as performance relates to baseline (Figure 6). Males demonstrate the expected pattern of greatest interference by the phonetic visual stimuli, limited interference by semantic stimuli, and a facilitation effect when the auditory task is paired with facial presentations. On simple effects testing phonetic stimuli were found to cause significantly greater levels of interference in both the LVF and RVF when compared to the semantic and facial stimuli possibly resulting from the greater sharing of processing mechanisms involved in both the CV dichotic task and the phonetic visual task. Females also demonstrate the same general pattern, in that the greatest interference occurs during phonetic trials and the least interference is evident during facial trials. This is consistent with the findings of Rollins and Hendricks (1980) who found that processing for the semantic properties of words presented visually could occur in relative independence from an auditory task requiring acoustic analysis.

Pronounced gender differences exist as dual-task performance relates to baseline performance. Males demonstrate performance above baseline on three of the six VF/VT conditions although the differences did not reach statistical significance. Where males show no significant differences between LVF and RVF for any of the three types of visual stimuli, females demonstrate

significant differences for both semantic and facial stimuli. As expected, significantly greater levels of interference occur with RVF semantic presentations than LVF. As discussed above, this interference may result from a greater degree of sharing of processing mechanisms by the auditory and visual stimuli.

Facial stimuli, when combined with the auditory task for females, present a somewhat surprising finding. In this case RVF-facial trials were significantly different than LVF trials with performance during RVF trials being at baseline levels. One could argue, that if indeed as shown in Experiment 1, that females exhibit a RVF advantage on the facial task employed in this study than perhaps the processing of emotional faces is performed in the LH utilizing separate mechanisms to those employed for the auditory task (Wickens, 1984). Based on this hypothesis, LVF trials might perhaps cause greater interference as processing resources are channeled away from the auditory task in order to process the degraded signal arriving from the RH. Shiffrin and Schneider (1977) suggest that degraded signals may not proceed fully through automatic processing and so require earlier use of controlled processes. As Friedman and Polson (1981) propose, the amount of available resources might be increased in both hemispheres in response to increased demand. In this case, if both the facial task and CV dichotic task are utilizing different LH mechanisms and

additional resources are needed to drive these mechanisms then there might be a corresponding increase in RH resources perhaps increasing RH efficiency to deal with LE trials. Interestingly, LE accuracy during RVF-facial presentations increased by 1.5% over baseline LE trials lending some support for the Friedman and Polson (1981) proposal. In addition, when collapsed across sex, LE trials with facial presentations yielded an overall accuracy level of 74.5% compared to a LE baseline level of 70.7%. Visual accuracy to facial stimuli was identical for both left and right ear trials demonstrating that there was not a tradeoff between auditory and visual accuracy for LE relative to RE trials. Auditory accuracy for RE trials was only slightly below baseline.

The proposal by Heilman and colleagues (Heilman & Van Den Abell, 1979; Bowers & Heilman, 1980) regarding RH activation of the LH would be difficult to assess in female subjects if indeed facial stimuli demonstrated a LH preference. Males however, display a non-significant facilitation of RE performance by LVF-Facial trials while not demonstrating a facilitation of LE performance by RVF-verbal presentations. This is in keeping with the Heilman and colleagues proposal. The possibility exists that the RE-LH performance for females has become data-limited (Norman & Bobrow, 1975) and no additional activation or resources can increase the level of

performance while LE-RH performance is resource limited and so can be improved by additional resources.

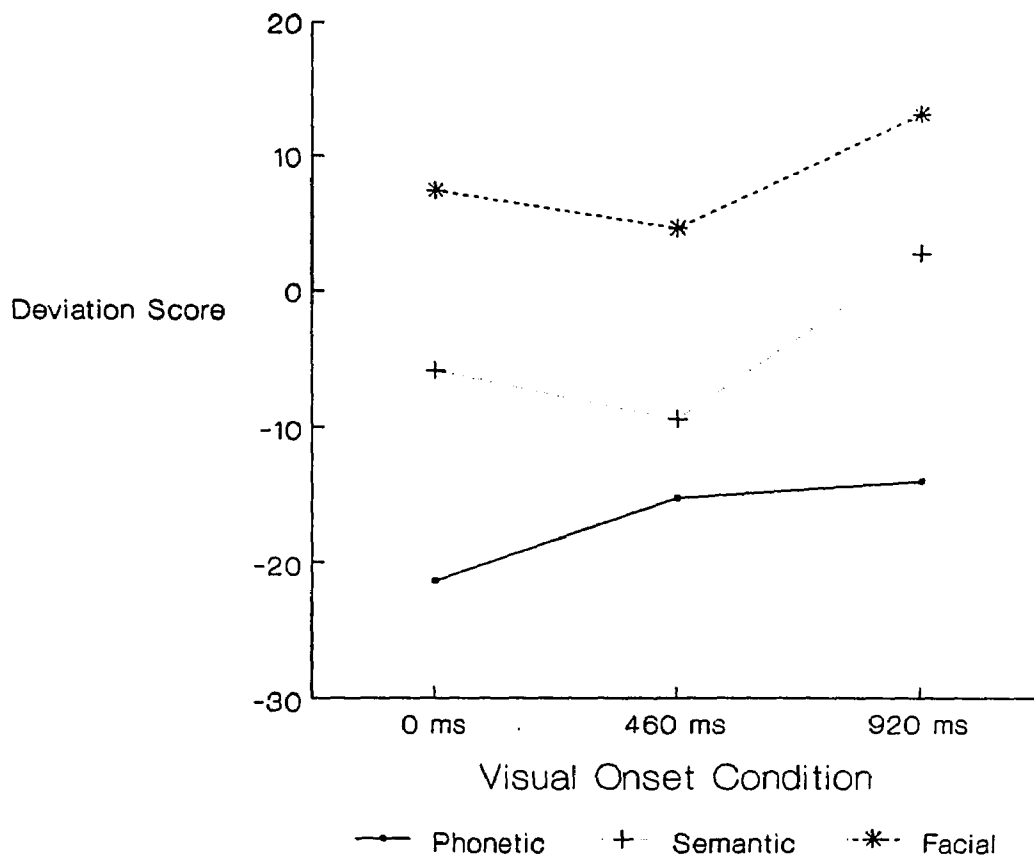
The deviation scores further confirm the effect found for auditory accuracy. For both males and females (See Figure 13) and for both LVF and RVF (See Figure 14), interference is greater for phonetic, less so for semantic, and facial stimuli have a minor facilitative effect. As discussed above, the phonological nature of both the CV task and phonetic visual stimuli cause the probable sharing of processing mechanisms. Semantic stimuli on the otherhand may have a greater likelihood of being processed by the RH. Sidtis, Volpe, Wilson, Rayport, and Gazzaniga (1981) in a study with two split-brain patients found both to have semantic information processing capability in their right hemispheres while their abilities differed on phonological processing. If indeed both semantic and facial stimuli have the potential to be either partly or fully processed in the right hemisphere then additional support is lent to the theory that each hemisphere possesses independent processing resources and mechanisms (Friedman and Polson, 1981) and so allows dual-task processing to occur relatively unencumbered.

It had been predicted that altering the visual onset times would differentially affect performance on the dual-task. The type of visual stimulus was expected to influence dual-task performance based on two primary

factors: 1) similarity to the CV dichotic task; and 2) time out from the conclusion of the dichotic pair. No significant dual-task findings were evident, however, as Figure 15 demonstrates trends were present in the expected direction. Interference for phonetic visual stimuli decreased along the continuum, 0ms, 460ms, 920ms while facial visual stimuli appears to have had no interference effect at any of the three conditions as would be predicted if multiple processing resources were available. Where visual type had the expected results across sex, the differences between sex were somewhat surprising. Females showed greater levels of interference on the dual-task phonetic visual condition than did males. There is evidence to suggest (Beaton, 1985) that males typically have greater lateralization of function than do females who are more bilaterally represented for such functions as language. In this study however, only females displayed a significant RE advantage on baseline CV trials although both males and females demonstrated both reaction time and accuracy scores in the expected direction; RE better than LE. In addition, of the nine subjects in the study who demonstrated a RE advantage for both reaction time and accuracy, six were females. One would expect greater interference from phonetic stimuli for those individuals with strong LH language lateralization. As discussed above, the behavioral indices (i.e. dichotic listening)

FIGURE 15

**The Effect of Visual Type and Visual Onset Condition
on Mean Total Deviation Scores per Subject**



may not always be good predictors of language lateralization as a result of the variability in the ascending auditory system (Sidtis, 1982). Interestingly, when the six RE advantage subjects are compared to the three non-RE advantage subjects a large difference between the mean auditory accuracy during phonetic visual presentations for each group is observed. Where the non-RE advantage group was at baseline (79%) the RE advantage group averaged 66% correct. These results should be considered cautiously as the N in the non-RE advantage group was extremely small. If the non-RE advantage group is representative of greater bilateral language representation than that present in the RE advantage group then it would be predicted that a dual phonetic task could be divided between the two hemispheres without significant processing cost. In contrast, the RE advantage group would be limited to the LH for processing with perhaps only early stage processing occurring in the RH (Moscovitch & Klein, 1980). The result would be greater competition between the visual and auditory phonetic stimuli for the limited processing mechanisms in the LH.

GENERAL DISCUSSION

The present study set out to examine ear of CV presentation, visual field of the unilateral visual presentation, type of visual stimuli, and temporal location of the visual presentation as factors which influence performance under dual-task conditions. The goals were two-fold: 1) to evaluate a special case of multiple resource theory; and 2) to determine the factors most influential to the development of interference and facilitation effects. In order to determine the effects of the visual task upon the auditory task and vice versa each task was run singly to obtain baseline data.

In Experiment 1 significant and non-significant right visual field differences were found for both semantic and phonetic stimuli. Unexpectedly, females displayed a significant RVF RT advantage for phonetic stimuli while males did not. Males did, however, demonstrate a LVF advantage approaching significance for facial stimuli while females displayed the reverse. It is interesting to note that on both the visual verbal and auditory baselines, females exhibited greater asymmetries than their male counterparts with both significant RVF and RE advantages being evident. This is significant in light of the suggestions in the literature (Beaton, 1985) that males are more lateralized for specific functions, like language, and so should display greater asymmetries

then females.

The dual-task conditions studied in Experiment 2 demonstrated a number of interesting findings. As expected, the phonetic visual task impeded the processing of the CV dichotic task to a greater extent than either the semantic or facial tasks. The semantic condition, although appearing to share certain mechanisms and/or resources did not appear to severely limit auditory processing. Overall processing of facial stimuli proceeded in, what seems to be, relative independence from the CV task. In certain VF x Ear conditions non-significant increases in auditory accuracy above baseline were observed during trials showing facial stimuli.

When VF is considered, it became evident that many effects arose as a result of interactions at specific levels of VF and VT although the exact nature of these interactions were sometimes unclear. For instance, right visual field presentations may have slowed auditory processing relative to LVF. Alternatively, LVF presentations may have decreased reaction time relative to RVF presentations as a result of RH activation (Bowers & Heilman, 1980).

The three visual onset conditions, unexpectedly, produced no significant effects on dual-task performance, although trends in the expected direction were present. This may have resulted from consistent levels of auditory processing occurring in the interstimulus interval

between the dichotic pair and binaural probe. In addition, five of the six subjects in the 460 ms condition displayed a RE advantage on the CV task while only two subjects in each of the 0 ms and 920 ms condition presented with a RE advantage on baseline assessment. Future studies should consider controlling for extent of ear advantage when placing subjects into experimental groups.

In general, the results of the present study appear to support the proposals by Friedman and Polson (1981) and Wickens (1984) regarding the presence of multiple resources and/or mechanisms. In addition, there appears to be some support for the premise that these mechanisms can operate independently with little or no processing cost to the other and that these separate mechanisms may reside in the LH and RH (Friedman & Polson, 1981). There was, however, some evidence in support of both an activation model (Heilman & Van Den Abell, 1979; Bowers & Heilman, 1980) and an attentional model (Kinsbourne, 1973), although neither appeared to be as able to explain the results to as great an extent as the model proposed by Friedman and Polson (1981).

The results appear to support the following conclusions and suggest that there may be a number of factors (i.e. multiple processing resources, activation effects, attentional biases) and that each plays varying roles in determining dual-task performance. 1) As the

processing requirements of the auditory and visual tasks become more dissimilar, processing interference declines. 2) Under very specific circumstances (i.e. facial visual presentations combined with LE auditory trials) performance during a dual-task may be enhanced above its single-task level. 3) Both structural limitations (i.e. mechanisms) and capacity limitations (i.e. resources) appear to affect dual-task performance, and where resources can be increased without the tasks sharing processing mechanisms, facilitation may result.

The intersubject variability observed during both Experiment 1 and Experiment 2 suggests that similar dual-task studies should consider the use of a completely within subject design and a larger N in order to more extensively examine the potential facilitative effects of non-verbal stimuli. The visual stimuli should be controlled for difficulty by adjusting the exposure times of the different types of stimuli. In the present study, semantic, phonetic, and facial stimuli varied in difficulty thereby making a direct comparison of the effects of each on dual-task processing confounded by two separate factors: 1) the processing resources and mechanisms required by each; and 2) the absolute difficulty of each stimulus.

Lastly, it appears that the use of both accuracy and reaction time measures is warranted in that they appear to assess somewhat different processes. It is

interesting to note that reaction time was somewhat more sensitive in detecting differences between visual field of presentation while the accuracy measure found significant differences between the three different types of visual stimuli. Trends were present in the expected direction for the other measure in each of these two cases, although they failed to reach statistical significance.

Appendix A

Handedness Questionnaire

Subject's name _____

Show me how you:

- | | | |
|-----------------------------|---|---|
| 1) throw a ball | R | L |
| 2) hammer a nail | R | L |
| 3) use scissors | R | L |
| 4) turn a door knob | R | L |
| 5) dial a telephone | R | L |
| 6) comb your hair | R | L |
| 7) deal cards | R | L |
| 8) play tennis or ping pong | R | L |
| 9) strike a match | R | L |
| 10) write your name | R | L |

Total R_____ L_____

Appendix B

CERTIFICATE OF INFORMED CONSENT

NAME OF
EXPERIMENT: _____NAME OF
EXPERIMENTER: _____

I understand that the project for which I am going to participate requires that I listen to sounds presented through headphones while watching very short duration visual presentations. All my questions regarding this project have been answered to my satisfaction.

At this time I understand that I may agree to participate or decline to participate in this project without any penalty whatsoever. Furthermore, I recognize that I may withdraw my participation at any point, or refuse to answer any question without any penalty.

Student's
name: _____Student's
signature _____

Age: Years: _____

Months: _____

Social Security #: _____

Date: _____

Appendix CVerbal Visual Stimuli
(Thorndike & Lorge, 1944)Semantic

Moose
Tiger
Hound
Skunk
Mouse
Zebra
Sheep
Camel

Whale
Snake
Eagle
Robin
Quail
Goose
Shark
Snail

Phonetic

Graph
Phone
Cough
Laugh
Phase
Alpha
Photo
Phial

Linen
Plane
Arena
Birch
Canoe
Diary
Medal
Sloop

Average Frequency

(approx. 25/million)

(approx. 24/million)

Appendix D

SUBJECT INSTRUCTIONS

Experiment #1

On the screen in front of you there will be a presentation of either a word or face. This visual presentation will appear either to the left or right of this center fixation point. I would like you to tell me, by using this switch in front of you marked "yes" or "no", whether the word or face that you saw during the trial belongs to your semantic category [or phonetic class] or is a "happy" face. Push the switch to the side marked "yes" when the stimulus fits the criterion of: "yes, it belongs to the semantic category of four-legged animals" [or "yes, it has an 'f' sound in it"] or "yes, it is a happy face. If it does not meet one of these criterion then push the switch to the side marked "no". Do you have any questions about the task?

Experiment #2

I will play a tape for you with consonant-vowel sounds on it. They will be the sounds "pa,ta,ka,ba,da and ga". You will first hear two sounds simultaneously, a different sound in each ear. You may hear a "pa" sound in the left ear and at the same time hear a "da" sound in the right ear. If the third sound matches either of the first two sounds, answer "same" by pushing the switch in front of you to the side marked "same". If the third sound does not match

either of the first two then answer "different" by moving the switch to the side marked "different". Let's try an example: If you hear a "ta" in your left ear and a "ga" in your right ear and one second later you hear a "ta", what would your answer be? As a second example let's say you hear a "ka" in your left year and a "ba" in your right ear and one second later you hear a "pa". What would the correct answer be?

Now that you understand that part let me describe the second task to you. In between the first pair of sounds and the third sound there will be a visual presentation of either a word or face. This visual presentation will appear on the screen in front of you to either the left or right of this center fixation point. I would like you to tell me by pressing this red button, whether the word or face that you saw during the trial belongs to your semantic category [or phonetic class] or is a happy face. You only need to press the button when the stimulus fits the criterion of "yes, it belongs to the semantic category of four-legged animals" [or "yes, it has an "f" sound in it"] or "yes, it is a happy face. If it does not meet one of these criterion, then it is not necessary to press the button.

I would like you to respond to whether the third sound is the same or different from the first pair of sounds before you press the button regarding the visual presentation. So the auditory stimulus is the primary task and the visual presentation is the secondary task. You may

want to respond to the visual stimulus first because it will end before the third sound begins, but do not. Wait until you hear the third sound and have responded "same" or "different" before pressing the red button, if necessary.

Throughout this study there will be an equal probability of the auditory task being same or different. In addition, there is an equal chance of the visual stimulus being to the left or the right of this center point. The visual stimulus will be of very short duration so your best chance of seeing all the visual stimuli will be to look directly at that center point throughout the study.

APPENDIX E

Experimental Design

Experiment 1 (n = 8)

Sex:	Male (n = 4)			Female (n = 4)		
Visual Type:	SEM	PHO	FACIAL	SEM	PHO	FACIAL
Visual Field: LVF						
RVF						

Experiment 2 (n = 18)

Visual Onset:	0ms			460ms			920ms		
Sex:	Male (n=3)		Females(n=3)	Males(n=3)		Females(n=3)	Males(n=3)		Females(n=3)
Ear:	LE & RE		LE & RE	LE & RE		LE & RE	LE & RE		LE & RE
Visual Type:	S	P	F	S	P	F	S	P	F
Visual Fd:									
LVF									
RVF									

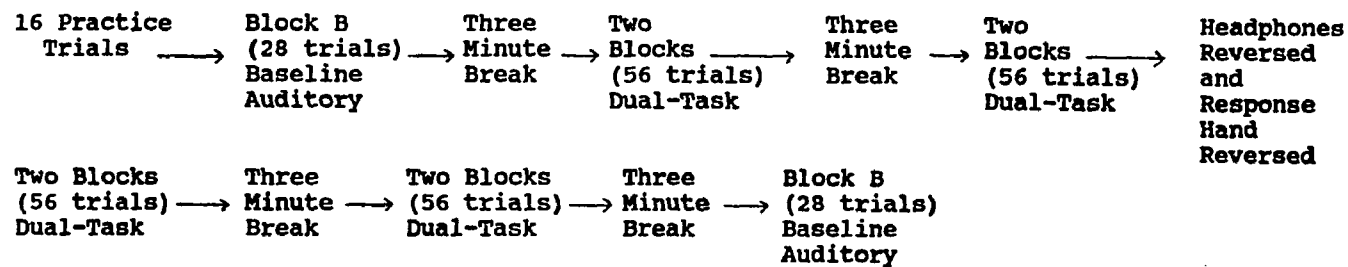
LE = Left Ear
 RE = Right Ear
 LVF = Left Visual Field
 RVF = Right Visual Field

S = Semantic
 P = Phonetic
 F = Facial

Appendix F

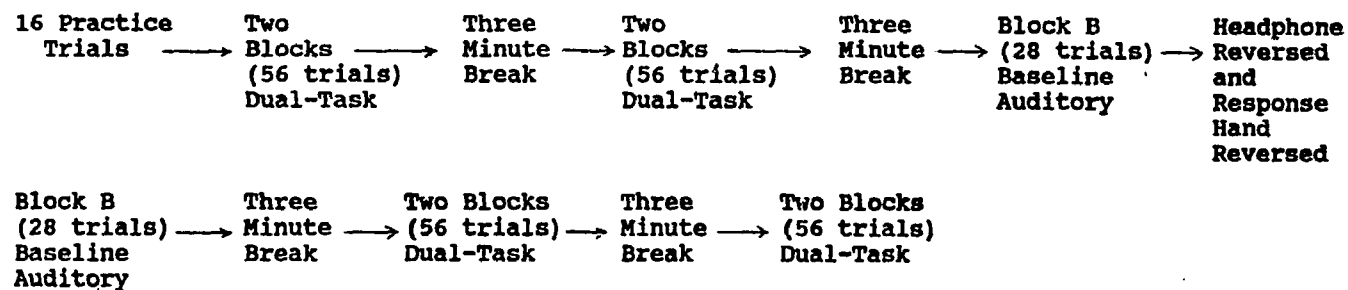
Sequence

1)



Sequence

2)



APPENDIX G

NAME _____ Date _____ EXP# _____
 RIGHT HANDED _____ SEX _____ M F
 HEARING PROBLEMS _____ EAR ORIENT: _____ N R
 NATIVE ENG. SP. _____ TAPE ORDER: _____ 1 2
 MUSICAL TRAINING _____ HOW LONG _____
 INSTRUMENT _____ HOW RECENT _____

CV

TRIAL	PROBE	RESPONSE	RT	SCORE	R	KEY	N	VS
1	K				R	Y	L	1
2	P					N		13
3	G					N		11
4	B					N		2
5	P				L	Y	R	7
6	K					N		12
7	T					N		3
8	T				R	Y	L	14
9	D				L	Y	R	10
10	T					N		8
11	P				R	Y	L	6
12	K					N		2
13	K				R	Y	L	9
14	B				L	Y	R	5
15	P					N		4
16	G				L	Y	R	8

CV TRIAL	PROBE	RESPONSE	RT	BLOCK A			VS
				SCORE	DF	R KEY L	
1	T					N	2
2	K					L Y R	11
3	D					N	4
4	B					N	7
5	T					L Y R	12
6	K					N	3
7	B					N	10
8	P					N	14
9	D					R Y L	2
10	D					N	6
11	D					L Y R	8
12	B					L Y R	5
13	P					R Y L	13
14	G					L Y R	1
15	G					N	12
16	P					N	13
17	T					N	11
18	G					R Y L	6
19	K					R Y L	.9
20	B					N	8
21	K					N	1
22	T					R Y L	3
23	G					R Y L	10
24	K					N	5
25	T					L Y R	7
26	G					L Y R	14
27	D					R Y L	4
28	P					N	9

CV	BLOCK B									
	TRIAL	PROBE	RESPONSE	RT	SCORE	DF	R	KEY	L	VS
	1	D					R	Y	L	7
	2	K					L	Y	R	4
	3	D					R	Y	L	5
	4	B					L	Y	R	6
	5	P					L	Y	R	1
	6	G					R	Y	L	8
	7	G					R	Y	L	9
	8	D						N		1
	9	P					L	Y	R	10
	10	K					R	Y	L	3
	11	T						N		5
	12	K						N		12
	13	P					L	Y	R	2
	14	G						N		7
	15	T						N		6
	16	P						N		8
	17	G						N		2
	18	B					L	Y	R	13
	19	K					R	Y	L	-4
	20	T						N		11
	21	K						N		1
	22	G					L	Y	R	5
	23	B					R	Y	L	8
	24	D						N		3
	25	D						N		14
	26	B						N		8
	27	P						N		1
	28	T						N		4

CV		BLOCK C								
TRIAL	PROBE	RESPONSE	RT	SCORE	DF	R	KEY	L	VS	
1	K						N		5	
2	K					L	Y	R	2	
3	D					L	Y	R	6	
4	G						N		1	
5	D						N		2	
6	B					R	Y	L	14	
7	P					R	Y	L	3	
8	G					L	Y	R	7	
9	P						N		8	
10	P					L	Y	R	7	
11	B					L	Y	R	2	
12	D					R	Y	L	5	
13	B					R	Y	L	1	
14	G						N		6	
15	P					L	Y	R	8	
16	D						N		6	
17	B						N		7	
18	T						N		3	
19	B						N		4	
20	P					R	Y	L	11	
21	D						N		10	
22	T					L	Y	R	12	
23	T					R	Y	L	4	
24	K						N		13	
25	G					R	Y	L	7	
26	T						N		9	
27	T						N		6	
28	K						N		3	

CV		BLOCK D							
TRIAL	PROBE	RESPONSE	RT	SCORE	DP	R	KEY	L	VS
1	B						N		10
2	P						N		3
3	G						N		5
4	B					R	Y	L	8
5	B						N		1
6	K					L	Y	R	7
7	T						N		6
8	T					R	Y	L	10
9	D						N		8
10	D						N		13
11	K					L	Y	R	1
12	T					L	Y	R	14
13	G					L	Y	R	9
14	P						N		11
15	P					R	Y	L	6
16	D					L	Y	R	5
17	D						N		7
18	G					R	Y	L	13
19	G						N		12
20	G						N		4
21	P						N		2
22	T					R	Y	L	4
23	B					L	Y	R	11
24	D					R	Y	L	3
25	T					L	Y	R	1
26	B						N		9
27	K						N		14
28	K					R	Y	L	12

APPENDIX H

Experiment 1 (%)						
<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>Tail Prob</u>	<u>GG</u>
MEAN	315673.64120	1	315673.64120	4951.12	0.0000	
SEX	123.52085	1	123.52085	1.94	0.2134	
ERROR	382.54828	6	63.75805			
FIELD	52.92001	1	52.92001	0.89	0.3820	
FS	13.22999	1	13.22999	0.22	0.6539	
ERROR	356.97329	6	59.49555			
TYPE	5262.94286	2	2631.47143	17.02	0.0003	.015
TS	1004.78049	2	502.39024	3.25	0.0745	.0962
ERROR	1855.22685	12	154.60224			
FT	27.04874	2	13.52437	0.82	0.4627	.4324
FTS	13.99625	2	6.99812	0.43	0.6629	.6016
ERROR	197.37169	12	16.44764			

Experiment 1 (RT)						
<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>Tail_Prob</u>	<u>GG</u>
MEAN	385.83783	1	385.83783	9129.28	0.0000	
SEX	0.05064	1	0.05064	1.20	0.3157	
ERROR	0.25358	6	0.04226			
FIELD	0.01200	1	0.01200	14.86	0.0084	
FS	0.00383	1	0.00383	4.75	0.0722	
ERROR	0.00485	6	0.00081			
TYPE	0.01249	2	0.00624	0.80	0.4738	.4452
TS	0.02344	2	0.01172	1.49	0.2635	.2680
ERROR	0.09417	12	0.00785			
FT	0.01067	2	0.00534	2.41	0.1321	.1528
FTS	0.00225	2	0.00113	0.51	0.6139	.5627
ERROR	0.02660	12	0.00222			

Experiment 2 Auditory (‡)

<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>Tail Prob</u>	<u>GG</u>
SEX	914.53881	1	914.53881	0.89	0.3665	
ONSET	1428.43193	2	714.21596	0.69	0.5208	
SO	5.41003	2	2.70502	0.00	0.9974	
1-ST COVAR	12055.14160	1	12055.14160	11.69	0.0057	0.8273
ERROR	11343.08732	11	1031.18976			
AUD	153.66646	1	153.66646	0.54	0.4797	
AS	174.68522	1	174.68522	0.61	0.4518	
AO	37.23488	2	18.61744	0.06	0.9376	
ASO	1154.70277	2	577.35139	2.01	0.1801	
1-ST COVAR	867.48889	1	867.48889	3.02	0.1100	0.2995
ERROR	3157.28324	11	287.02575			
VISFD	121.65006	1	121.65006	1.32	0.2738	
VS	10.53374	1	10.53374	0.11	0.7416	
VO	542.92272	2	271.46136	2.93	0.0917	
VSO	232.40111	2	116.20055	1.26	0.3197	
ERROR	1110.10867	12	92.50906			
AV	0.14005	1	0.14005	0.00	0.9671	
AVS	0.89449	1	0.89449	0.01	0.9170	
AVO	240.02487	2	120.01243	1.52	0.2582	
AVSO	128.05484	2	64.02742	0.81	0.4676	
ERROR	948.19513	12	79.01626			
TYPE	3102.64490	2	1551.32245	10.43	0.0005	0.0007
TS	375.82073	2	187.91036	1.26	0.3008	0.3001
TO	1268.94330	4	317.23583	2.13	0.1078	0.1126
TSO	1273.92888	4	318.48222	2.14	0.1067	0.1115
ERROR	3569.34292	24	148.72262			
AT	12.91453	2	6.45727	0.04	0.9564	0.9240
ATS	356.42362	2	178.21181	1.23	0.3097	0.3046
ATO	178.21987	4	44.55497	0.31	0.8699	0.8274
ATSO	62.33363	4	15.58341	0.11	0.9787	0.9590
ERROR	3473.73535	24	144.73897			
VT	555.80083	2	277.90042	3.68	0.0403	0.0476
VTS	772.35204	2	386.17602	5.12	0.0141	0.0185
VTO	191.19708	4	47.79927	0.63	0.6436	0.6248
VTSO	455.76522	4	113.94130	1.51	0.2309	0.2383
ERROR	1811.24161	24	75.46840			
AVT	102.60956	2	51.30478	0.50	0.6151	0.5369
AVTS	44.57011	2	22.28505	0.22	0.8077	0.7085
AVTO	46.19269	4	11.54817	0.11	0.9772	0.9329
AVTSO	92.08601	4	23.02150	0.22	0.9232	0.8515
ERROR	2482.48534	24	103.43689			

Experiment 2 Auditory (RT)

<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>Tail Prob</u>	<u>GG</u>
SEX	0.03784	1	0.03784	0.96	0.3485	
ONSET	0.00664	2	0.00332	0.08	0.9198	
SO	0.03892	2	0.01946	0.49	0.6236	
1-ST COVAR	1.91397	1	1.91397	48.51	0.0000	
ERROR	0.43400	11	0.03945			
AUD	0.02075	1	0.02075	3.50	0.0884	
AS	0.01126	1	0.01126	1.90	0.1958	
AO	0.01685	2	0.00843	1.42	0.2829	
ASO	0.00019	2	0.00009	0.02	0.9842	
1-ST COVAR	0.01154	1	0.01154	1.94	0.1907	
ERROR	0.06530	11	0.00594			
VISFD	0.01196	1	0.01196	6.00	0.0306	
VS	0.00036	1	0.00036	0.18	0.6804	
VO	0.00641	2	0.00320	1.61	0.2407	
VSO	0.00004	2	0.00002	0.01	0.9889	
ERROR	0.02392	12	0.00199			
AV	0.00003	1	0.00003	0.02	0.8912	
AVS	0.00184	1	0.00184	1.25	0.2862	
AVO	0.00051	2	0.00025	0.17	0.8447	
AVSO	0.01508	2	0.00754	5.10	0.0250	
ERROR	0.01775	12	0.00148			
TYPE	0.02182	2	0.01091	1.51	0.2422	.2458
TS	0.01917	2	0.00959	1.32	0.2852	.2793
TO	0.03681	4	0.00920	1.27	0.3093	.3161
TSO	0.01009	4	0.00252	0.35	0.8428	.7591
ERROR	0.17398	24	0.00725			
AT	0.00144	2	0.00072	0.33	0.7235	.7108
ATS	0.00304	2	0.00152	0.69	0.5099	.5021
ATO	0.00717	4	0.00179	0.82	0.5273	.5218
ATSO	0.00327	4	0.00082	0.37	0.8260	.8153
ERROR	0.05268	24	0.00220			
VT	0.00159	2	0.00080	0.37	0.6966	.6763
VTS	0.00025	2	0.00012	0.06	0.9447	.9310
VTO	0.00970	4	0.00243	1.12	0.3717	.3708
VTSO	0.00147	4	0.00037	0.17	0.9518	.9405
ERROR	0.05210	24	0.00217			
AVT	0.00627	2	0.00313	1.65	0.2122	.2197
AVTS	0.00095	2	0.00047	0.25	0.7804	.7184
AVTO	0.00303	4	0.00076	0.40	0.8069	.7555
AVTSO	0.00581	4	0.00145	0.77	0.5572	.5277
ERROR	0.04544	24	0.00189			

Experiment 2 Visual (%)

<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>Tail Prob</u>	<u>GG</u>
MEAN	1359329.09457	1	1359329.09457	2744.07	0.0000	
SEX	72.56965	1	72.56965	0.15	0.7086	
ONSET	979.16857	2	489.58428	0.99	0.4006	
SO	373.20017	2	186.60008	0.38	0.6940	
ERROR	5944.439	12	495.36996			
AUD	25.76464	1	25.76464	0.14	0.7193	
AS	1203.22246	1	1203.22246	6.32	0.0272	
AO	58.28902	2	29.14451	0.15	0.8597	
ASO	701.58074	2	350.79037	1.84	0.2004	
ERROR	2283.79015	12	190.31585			
VISFD	984.74743	1	984.74743	3.20	0.0990	
VS	87.14739	1	87.14739	0.28	0.6044	
VO	144.86563	2	72.43281	0.24	0.7940	
VSO	411.23064	2	205.61532	0.67	0.5309	
ERROR	3695.17891	12	307.93158			
AV	0.93352	1	0.93352	0.01	0.9404	
AVS	614.08173	1	614.08173	3.83	0.0739	
AVO	12.09619	2	6.04810	0.04	0.9631	
AVSO	78.00856	2	39.00428	0.24	0.7877	
ERROR	1922.74348	12	160.22862			
TYPE	11270.07422	2	5635.03711	11.88	0.0003	0.0005
TS	924.90723	2	462.45362	0.97	0.3918	0.3840
TO	902.45014	4	225.61253	0.48	0.7533	0.7322
TSO	193.40912	4	48.35228	0.10	0.9808	0.9726
ERROR	11388.06545	24	474.50273			
AT	7.80259	2	3.90129	0.02	0.9791	0.9608
ATS	786.52265	2	393.26133	2.13	0.1410	0.1526
ATO	458.48805	4	114.62201	0.62	0.6524	0.6217
ATSO	586.58687	4	146.64672	0.79	0.5410	0.5205
ERROR	4435.29362	24	184.80390			
VT	474.68490	2	237.34245	1.03	0.3718	0.3448
VTS	15.10259	2	7.55130	0.03	0.9678	0.9041
VTO	712.71299	4	178.17825	0.77	0.5527	0.5051
VTSO	141.18854	4	35.29714	0.15	0.9596	0.8988
ERROR	5522.82140	24	230.11756			
AVT	603.04587	2	301.52293	1.73	0.1981	0.2045
AVTS	463.20337	2	231.60168	1.33	0.2829	0.2819
AVTO	936.30195	4	234.07549	1.35	0.2821	0.2882
AVTSO	818.71902	4	204.67975	1.18	0.3461	0.3466
ERROR	4174.93715	24	173.95571			

Deviation Scores

<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>Tail Prob</u>	<u>GG</u>
MEAN	4020.54148	1	4020.54148	2.24	0.1602	
SEX	324.37965	1	324.37965	0.18	0.6782	
ONSET	2482.60474	2	1241.30237	0.69	0.5194	
SO	161.65155	2	80.82578	0.05	0.9561	
ERROR	21522.87129	12	1793.57261			
AUD	643.07948	1	643.07948	0.63	0.4442	
AS	214.20381	1	214.20381	0.21	0.6561	
AO	1824.94943	2	912.47472	0.89	0.4368	
ASO	896.04673	2	448.02336	0.44	0.6564	
ERROR	12328.33515	12	1027.36126			
VISFD	13.75112	1	13.75112	0.07	0.7965	
VS	462.58947	1	462.58947	2.34	0.1522	
VO	698.15406	2	349.07703	1.76	0.2129	
VSO	456.56111	2	228.28055	1.15	0.3481	
ERROR	2374.00061	12	197.82228			
AV	87.27458	1	87.27458	0.35	0.5673	
AVS	260.26125	1	260.26125	1.03	0.3298	
AVO	344.08618	2	172.04309	0.68	0.5241	
AVSO	221.75682	2	110.87841	0.44	0.6543	
ERROR	3026.80439	12	252.23370			
TYPE	22844.02079	2	11422.01040	15.41	0.0000	.0001
TS	5942.90683	2	2971.45342	4.01	0.0315	.0317
TO	984.31769	4	246.07942	0.33	0.8537	.8530
TSO	2156.21669	4	539.05417	0.73	0.5821	.5816
ERROR	17789.53321	24	741.23055			
AT	129.19519	2	64.59759	0.18	0.8398	.8137
ATS	127.31078	2	63.65539	0.17	0.8419	.8159
ATO	419.51062	4	104.87766	0.29	0.8844	.8638
ATSO	809.62317	4	202.40579	0.55	0.7001	.6798
ERROR	8814.72826	24	367.28034			
VT	1204.18234	2	602.09117	7.14	0.0037	.0060
VTS	115.21575	2	57.60788	0.68	0.5147	.4946
VTO	187.01105	4	46.75276	0.55	0.6979	.6732
VTSO	649.53214	4	162.38304	1.92	0.1389	.1514
ERROR	2024.58630	24	84.35776			
AVT	1319.59232	2	659.79616	1.41	0.2643	.2650
AVTS	920.17403	2	460.08702	0.98	0.3894	.3755
AVTO	1302.39150	4	325.59788	0.69	0.6032	.5760
AVTSO	652.24948	4	163.06237	0.35	0.8430	.8041
ERROR	11253.79376	24	468.90807			

Baseline Auditory
ANOVA Summary Table

<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>Tail Prob</u>	<u>GG</u>
Between Subjects:						
SEX	409.3878	1	409.3878	1.6903	0.2120	
Residual	3875.2511	16	242.2032			
Within Subjects:						
EAR	1030.4100	1	1030.4100	7.0684	0.0172	
EAR by SEX	238.1878	1	238.1878	1.6339	0.2194	
Residual	2332.4422	16	145.7776			

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