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Single vs. Multiple Resources in Divided Attention: A Cross-Modal Test of the Independence of Hemispheric Resource Supplies

by

Chris M. Herdman

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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Date: August 19, 1983

Abstract

According to the limiting case of a multiple resources approach, the cerebral hemispheres are viewed as independent and limited capacity pools of attentional resources. The present study tested this model using tasks that demanded resources from the same vs. different resource pools (complete and no overlap situations, respectively). This was accomplished by combining a verbal memory load task with a tone memory task that required either left or right hemisphere resources depending on which ear was attended to. Single-to-dual task performance decrements were found on the verbal memory load task during both types of tone memory trials. However, performance tradeoffs between the verbal memory and tone memory tasks only occurred during right ear tone trials when there was presumed to be complete overlap in resource demand. The results support the limiting case of a multiple resources approach, whereas, the single-capacity model of attention, as well as the selective activation and functional cerebral distance models of hemispheric processing were found wanting. Furthermore, the results indicate that the tone memory task may have demanded resources independent of resource allocation policy. This type of resource demand was termed mandatory processing and it is suggested that it may be important in other situations where attentional processes are involved.

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I. INTRODUCTION

The primary goal of the following research is to test a model of divided attention performance that views the cerebral hemispheres as independent and limited capacity attentional resource pools. A comparison is made between this model and a single capacity model, which postulates the existence of only one pool of attentional resources.

Early theories of attention were based on the assumption that some sort of "bottleneck," or structural limitation of processing, occurs at a particular stage in the perceptual system. This bottleneck was believed to constrain the ability to divide attention by allowing only one stimulus to be operated upon at a time. Several theories advocating this structural model of attention were proposed and most differ only in respect to where the bottleneck was placed in the processing sequence. Among the many contributors to this type of theory were Broadbent (1958), who proposed the first selective filter model, Treisman (1960), who expanded Broadbent's model and "liberalized" the selective filter in her attenuation model, Deutsch and Deutsch (1963), who were responsible for shifting the selective filter towards the response stage of processing, and Norman (1968) who reformulated the Deutsch and Deutsch model.

Neisser (1967) was the first to step away from a structural model. In his "analysis-by-synthesis" approach, he highlighted the interaction between a stimulus and stored information. Neisser's change in approach led to the major shift represented by Kahneman's (1973) formulation of a capacity model of attention in which attention was thought to be allocated within a single, limited capacity system.

Kahneman (1973) hypothesized that there are two different types of input involved in mental activity. One type of input activates processing structures, and includes environmental inputs as well as inputs from internal neural structures. In this view, structures are similar to the structural bottlenecks postulated by the early selective attention theorists in that they can only process one input at a time.

The other type of input involved in mental activity was labelled effort, capacity, or attention. According to Kahneman (1973), this type of input is limited, in that only a certain amount can be taken from a finite attentional "pool" and applied to any given processing situation. The actual amount that is applied is determined by an allocation policy, which is a central element in the model. Allocation policy is influenced by unconscious dispositions and conscious intentions, and it is also sensitive to the "demands" of an activity. Depending upon the tasks being performed, the allocation policy may be used to allocate attention to one activity or divide it among many. If a task becomes more difficult, or if it is emphasized as being more important than others, then attention can be focused on that task. Therefore, the model focuses on determining how much attention a certain task demands in order to be performed at a specific level.

Evidence which supports the idea that attentional capacity is limited comes from shadowing experiments in which messages presented to the unattended ear are shown to undergo different amounts of processing, depending on the difficulty of the task presented to the attended ear. For example, Zelniker (1971) combined a shadowing task with delayed auditory feedback. Subjects were required to repeat a message presented to the attended ear and their vocalizations were presented to the unattended ear a fraction of a second later. The dependent measure was the number of "stutters" made while repeating the attended message. Zelniker (1971) found that when the shadowing task was difficult, fewer stutters were made than when the shadowing task was easy. Kahneman's (1973) capacity model explains these rather counterintuitive results by suggesting that a difficult shadowing task demands more attention, and thus less attention was left for processing the unattended input. Consequently, less disruption and fewer stutters were caused by the delayed auditory feedback. Note that a structural theory would predict no effect of delayed auditory feedback to the unattended channel, nor any differential effects caused by variation in shadowing difficulty, because all attention is assumed to be focused on the attended sensory channel.

The capacity model of attention was also based on the assumption that as a subject becomes more practiced at a task, fewer "attentional units" are required to perform. Consequently, as expertise increases, attentional units are freed for allocation to a second task. This assumption was supported by evidence obtained by Underwood (1974), who looked at subjects' performance in reporting the presence of a digit among a list of sixteen pairs of words. He found that a highly practiced subject performed only slightly better than novice subjects in detecting a digit presented to the attended ear. However, when the digit was presented to the unattended ear, the practiced subject performed far better than novices. This suggests that practice decreased the amount of attentional resources needed to perform the shadowing task, and consequently, extra resources could be allocated to detect digits presented to the unattended ear.

Norman and Bobrow (1975) expanded Kahneman's (1973) model, introduced some new concepts, and suggested a methodology for investigating complex cognitive processes. One contribution they made was to subsume the concepts of effort, capacity, and attention under the term "attentional resources." They also made an important distinction between "resource-limited" and "data-limited" processes. A resource-limited process is one in which an increase in the amount of processing resources leads to improved performance. In contrast, data-limited processes are those that are independent of allocation of resources, insofar as an increase in the amount of processing resources will not increase performance. Norman and Bobrow (1975) point out that up to a certain point of resource allocation most tasks are resource-limited, but beyond that point they are data-limited. Furthermore, when more than one process competes for the same limited resources, then considering the "performance-resource functions" underlying the processes is useful for predicting changes in performance as a function of shifts in attention. The assumption is that shifts in attention are accompanied by shifts in resource allocation.

A performance-resource function is a hypothetical curve in which performance on a given task is plotted against the amount of resources a subject is allocating to that task. If a fixed amount of resources are assumed to be available for processing (L), tasks performed concurrently compete for these resources but will not interfere with each other unless L is exceeded. Using Zelniker's (1971) experiment as an example, if the primary task (shadowing) required Rp resources, then the amount of resources available for processing the secondary channel, Rs, would be equal to the maximum limit of resources minus Rp (e.g., Rs = L - Rp). When the shadowing task was easy, L - Rp was larger than when the shadowing task was difficult. Hence, with an easy shadowing task, there were more resources remaining to process the delayed auditory feedback, in this case to the subject's detriment.

Note that in any given situation, mutual interference (resulting in performance decrements) occurs only when both processes are resource-limited. For example, if a task is functioning in its data-limited range, then a decrement of resources previously allocated to performing that task will have no effect on the level of performance. On the other hand, the performance level of a resource-limited task would decrease if resources were taken away from it. In addition, the absolute decrement may not be equivalent across tasks. For example, for the case in which tasks are performed with different efficiency, and thus have different performance-resource slopes, as in Figure 1, a one unit decrement in allotted resources would result in differentially decremented performance levels for the two tasks (Navon & Gopher, 1979).

Dual-task methodology is extremely useful when investigating attentional resource allocation. In general, the methodology involves combining two tasks and comparing performance levels in the concurrent situation to single task baseline performance. An extension of this methodology involves changing which of the tasks is the primary task (e.g., by instructing the subject to pay more attention to one of the tasks). If both tasks are resource-limited and require resources from the same pool, then such a manipulation should result in a shift in resource allocation, and performance on the task receiving more resources (e.g., more attention) should increase while performance on the task receiving fewer resources should decrease.

Kahneman's single capacity model has been quite successful in accounting for data pertaining to the divided attention literature (Lindsay, 1970; Lindsay, Taylor, & Forbes, 1968; Moray & O'Brien, 1967; Ninio & Kahneman, 1973; Treisman, 1970; Treisman & Fearnby, 1971; Underwood, 1974;

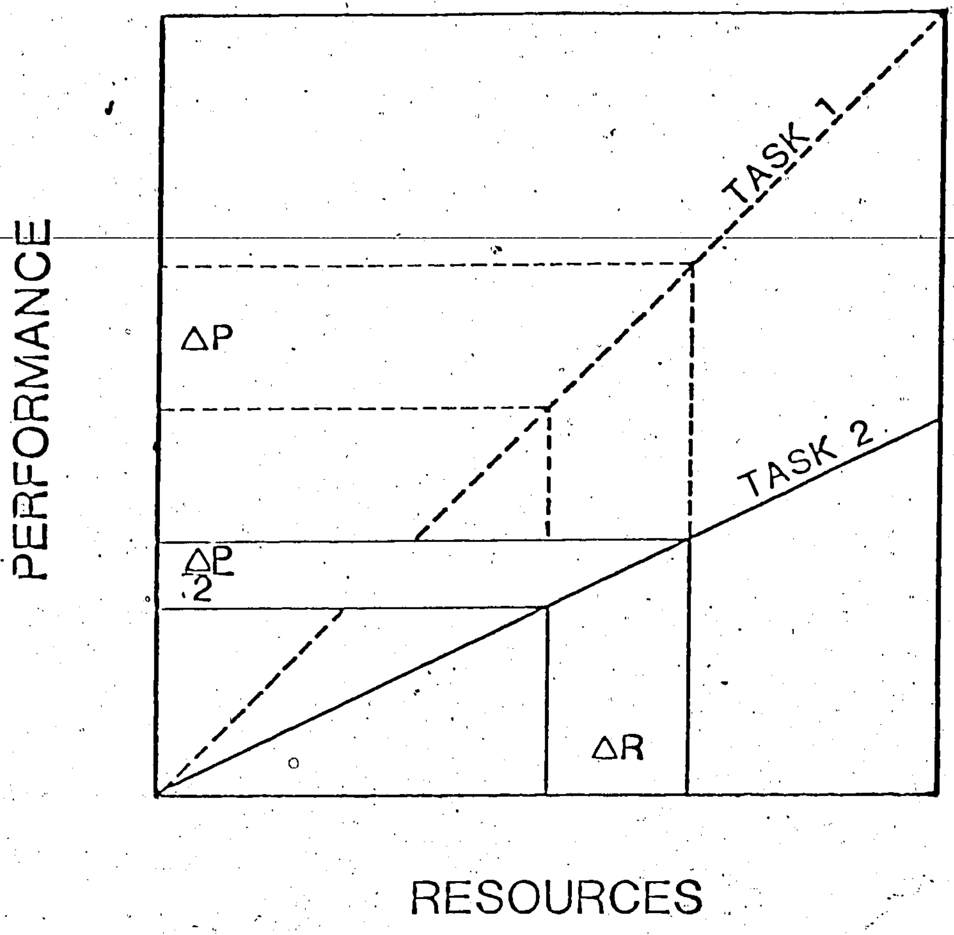

Figure 1. Hypothetical performance resource curves representing tasks differing in processing efficiency.

Zelniker, 1971). In addition, the dual task methodological considerations offered by Norman and Bobrow have added considerably to the testing of the model. However, the underlying assumption of a single capacity system has recently been severely criticized. For example, Navon and Gopher (1979; 1980) suggest that instead of just one resource pool, there may exist many different resource pools. Each pool is considered to have its own limited capacity, and each is independently able to allocate resources to a task that requires its resources. The degree to which two tasks can be time-shared depends, in part, upon the amount of overlap the tasks have in terms of demand for resources from a particular resource pool. Tasks that demand resources from the same pool (e.g., a situation of complete or partial overlap) should result in performance decrements when performed concurrently. Tasks that do not demand resources from the same pool (e.g., a situation of no overlap in resource demand) should not result in performance decrements when performed concurrently. As with the single capacity model, the capacity of the individual resource pools must be exceeded and the tasks must be operating in their resource-limited range before performance decrements will be observed.

To test the assumption that resource pools are independent from one another, performance trade-offs between different task pairs can be compared. For example, if Task A and Task B demand resources from the same limited capacity resource supply, then a shift in focus of attention from

Task A to B should result in more resources being allocated to B and fewer to A. Consequently, performance on Task B should increase at the expense of decreased performance on Task A. If the allocation policy is reversed so that now Task A becomes primary, then Task A performance should increase as Task B performance decreases. On the other hand, if Task A does not utilize resources common to another task, C, (e.g., no-overlap in resource demand), then a shift in resource allocation policy should not result in performance changes. Note that although the strict single capacity model may predict differential performance decrements when tasks are combined (e.g., due to different performance - resource slopes), it cannot predict the absence of mutual performance trade-offs between resource-limited tasks, since all tasks are assumed to require processing resources from the same common pool.

Despite its elegance, there are several problems with Navon and Gopher's (1979; 1980) multiple resource model. The major difficulty is that they do not suggest a way to identify, a priori, the resource pools that are specific to a process or set of processes. Therefore, it is not clear how to test the model, because differences in resource demand overlap situations can always be postulated post hoc (Wickens, 1980).

In an attempt to overcome some of the problems faced by the multiple resources model, Friedman and Polson (1981) proposed testing a limiting case of the model, in which there are assumed to be just two independent and limited capacity resource pools that are associated with the two cerebral hemispheres. The assumptions underlying the model that are unique to it with respect to Navon and Gopher's model, are (1) that the hemispheres each consist of separate mechanisms that require resources; (2) that each hemisphere has an independent and limited supply of resources; (3) that both hemispheres are affected by a change in arousal level and this is reflected in the amount of resources available to perform a task; (4) that although both hemispheres may be able to perform most tasks by using their own resources, one hemisphere may be able to process a specific task more efficiently than the other, and this is reflected in the amount of resources required to obtain a certain level of performance; and (5) that the resources of each hemisphere are undifferentiated, in that all mechanisms within a hemisphere, whether cognitive, motor, or perceptual, can draw from the same supply of resources.

The set of resources used to perform a task is referred to as its resource composition, and may consist of resources that are drawn from either or both hemispheres. Thus, in dual task situations, several combinations of task interference or non-interference may occur. When the two tasks share the same hemispheric resource pool this is a case of complete overlap in resource demand. Thus, performance decrements and task trade-offs will be similar to those predicted by a single capacity model. However, if the tasks do not demand resources from the same hemisphere, then this is a case of non-overlapping resource compositions. In these instances, performance trade-offs and decrements are not predicted by the independent hemisphere resources model.

Friedman and Polson (1981) initially based their model on past experimental findings in the attentional and hemispheric-specialization literatures. The most useful hemispheric experiments for testing the model are those that used dual-task methodology, and in some cases, varied the resource demands of one of the tasks (e.g., by making the task more difficult; Hellige and Cox, 1976; Hellige, Cox, and Litvak, 1979). However, to review the multitude of hemispheric research that has been performed (e.g., see Luria, 1970; Sperry, 1961; 1968; 1969; Meyer and Sperry, 1956; Gazzaniga, 1970; 1972; Levy, Trevarthen, and Sperry, 1972; Kimura, 1967; White, 1969; Geffen, Bradshaw, and Wallace, 1971; Moscovitch, 1980; Gordon, 1980) is beyond the scope of this thesis. In general, it may be concluded that across studies findings have been contradictory, difficult to replicate, and lacking the consistency one would expect to find if the phenomena that have been reported are based on actual structural or functional differences between the hemispheres.

In an attempt to account for this variability, Kinsbourne (1973) proposed a "selective activation" model of peripheral-cerebral asymmetry of function. Kinsbourne (1970; 1973; 1974) suggested that laterality effects can be explained in terms of a shift in the balance of activation between the hemispheres. Accordingly, a peripheral field processing advantage on a certain task is alleged to be caused by a shift in the balance of activation or arousal between the two hemispheres. The actual arousal of a particular hemisphere is believed to depend upon the task being performed; if a task requires processing by primarily one hemisphere, then arousal is said to increase in that hemisphere. If one hemisphere is aroused more than the other, then attention is shifted toward the side of the body contralateral to the activated hemisphere, and consequently, performance on tasks presented to the contralateral side is enhanced.

In general, the selective activation model has been successful in explaining only a limited amount of data, and the hemispheric activation effects proposed by Kinsbourne are difficult to obtain (see for example, Geffen, Bradshaw, and Nettleton, 1972). Dual-task experiments that were designed to test the model have provided mainly contradictory evidence (Hellige and Cox, 1976; Hellige, Cox, and Litvak, 1978; Hicks, 1975; Kinsbourne and Cook, 1971; Smith, Chu, and Edmonston, 1977). In fact, the data from these experiments are better interpreted according to the independent resources model (see Friedman and Polson, 1981).

In an attempt to account for data which did not fit the selective activation model, Kinsbourne and Hicks (1978) proposed a new model based on the concept of "functional cerebral space." According to this view, the brain contains a limited amount of functional cerebral space, which is comprised of linked neural networks. Hemispheric activation is believed to involve a spread of neural activity from a central location, such that as a subject reaches a maximum level of performance, the amount of cerebral space that the activity occupies increases. In a dual task situation, the "distance" between the tasks in terms of functional space is dependent upon the locations of the respective task functions in the brain. The closer the foci, the greater the amount of interference that occurs when the tasks are performed simultaneously. Futhermore, tasks performed concurrently can be permitted to "... proceed at an undiminished rate" (Kinsbourne and Hicks, 1978, p. 347), thereby risking interference with each other, or, the rate of information transmission can be reduced to limit the extent to which the cerebral cortex is activated and thus decrease the chance of interference. That is, the spread of neural activation from a central location can be increased or limited, presumably at will.

An important point, though, is that the theory does not explicitly incorporate the concept of differential network activation for tasks that are being performed concurrently. Thus, when one task receives more attention, this results in greater activation of the network used to perform that task, as well as in a spread of activation to the network that performs the second task. Therefore, the activation of one network is not predicted to occur independently of other networks that have been concurrently activated.

The functional cerebral distance model, which was designed to address data from motor tasks, is somewhat vague with respect to localization of perceptual/cognitive processes in the hemispheres. It is stated that processes that are categorically similar (such as different spatial tasks) are assumed to be functionally close, and tasks performed better when presented to a particular peripheral field are considered to be localized in the contralateral hemisphere (Kinsbourne, 1982; Kinsbourne and Hiscock, 1983). The lateralization of perceptual and cognitive processes is hypothesized to have developed from the need to "... perform different classes of cognitive operations concurrently" (Kinsbourne, 1983, p. 416), so that there is the least possible amount of structural interference.

Even though Kinsbourne disclaims association with capacity models of task interference (Kinsbourne, 1982), the functional cerebral distance model is nevertheless compatible with a single-capacity attentional model that postulates structural interference as the basis for performance decrements between tasks (Kahneman, 1973; Norman and Bobrow, 1975). The closer the task functions are structurally, the greater the predicted interference.

The problem with the model is that it has been congruent with only a very limited set of data, that being data from tasks that involve motor movements (e.g., Briggs, 1975; Hicks, 1975; Hicks, Bradshaw, Kinsbourne, and Feigin, 1978; Hicks, Provenzano, and Rybstein, 1975; Kinsbourne and Cook, 1971). To explain data from situations in which perceptual performance is enhanced (e.g., Hellige and Cox, 1976), the model must rely on the selective activation model's concept of orientation bias. For example, a task which is processed in the left hemisphere is believed to result in a spread of activation to the homolateral orienting control center which "... tips the balance of orienting tendencies such that the vector resultant orientation is swung contralateral to the more active hemisphere" (Kinsbourne & Hicks, 1978, p.355). Therefore, a process involving a cognitive operation that is hemispherically specialized will result in an orienting bias to the contralateral peripheral field, and in <u>some</u> cases, performance on tasks presented to that field will be enhanced. However, the model does not dictate how to predict when an orienting biasing center will be activated. Also, the conditions during which this orienting biasing will offset structural interference effects are not elaborated. Therefore, the model is difficult to test using cognitive tasks, in that performance increments or decrements cannot be clearly predicted.

Both the selective activation model and the functional cerebral distance model can be subsumed under the independent hemisphere resources model, and the latter can account for situations in which the others succeed or fail. Friedman and Polson and their colleagues (Friedman, Polson, Dafoe, and Gaskill, 1982) have directly tested some of the assumptions of the independent hemisphere resources model. In their first experiment, a laterally-presented nonsense syllable naming task was paired with a centrally presented verbal memory load task, and subjects were instructed to emphasize performance on one or the other. The load task was assumed to require left hemisphere resources for subjects who showed a right visual field (left hemisphere) processing advantage on a lateralized version of it. For the nonsense syllable target task, both hemispheres were presumed capable of perceptually decoding the stimuli, but the left hemisphere was believed to be responsible for the actual verbal output. Therefore, the two types of visual field target task trials constituted two different dual task situations. On left visual field target trials, there was partial overlap in left hemisphere resource demand, because left hemisphere resources were required only for part of the target task, whereas, on right visual field target trials there was complete overlap in demand.

As predicted by the model, there were larger single to dual task decrements on right visual field trials for both the target and the load tasks. There was also a significant effect of task emphasis, in which load task decrements were greater during target task emphasis trials, and target task decrements were greater during load task emphasis trials. Thus, both differential decrements and performance tradeoffs were obtained on both tasks as a function of visual field, which is support for the existence of two resource supplies associated with the two hemispheres.

The second experiment provided support for the assumption of independence of resources between the hemispheres. Two different target tasks (physical and name matches of nonsense syllable pairs) were combined with the same left hemisphere load task (remembering nonsense syllables). Since the target task did not require a spoken response, it was assumed that both hemispheres could process the task completely. Once again, the target tasks were presented to either visual field, thereby creating different resource demand overlap situations. On left visual field target trials there was no overlap in resource demand, whereas on right visual field target trials there was complete overlap. It was found that single to dual task decrements were more severe during the right visual field target trials. Importantly, subjects were unable to trade performance on the left visual field trials, but were able to trade on right visual field trials. These studies support the main underlying assumptions of the model, namely, the existence of two resource supplies, and independence of resource accessibility between the hemispheres.

Although Friedman and her colleagues (Friedman, Polson, Dafoe, & Gaskill, 1982) have tested the independent resources model, it is necessary to test the assumptions further using tasks that are not processed in the visual modality, and which are performed more efficiently by the right rather than the left hemisphere. Although the primary purpose of the present research was to compare a single capacity model of attentional resource allocation with the limiting case of a multiple resources model, the secondary goals of this research were to (1) provide further support for the assumption of resource supply independence, (2) take steps toward testing the assumption of undifferentiated resources, and (3) compare the functional cerebral distance model to the independent hemisphere resources model.

To achieve these goals, two tasks that allowed us to examine different overlapping resource demand situations were combined. One task involved remembering three pronouncable nonsense words (CVCVCs). This task was previously used by Friedman and her colleagues (Friedman, Polson, Dafoe, and Gaskill, 1982) and found to require primarily left hemisphere resources for subjects who show a strong right visual field (left hemisphere) processing superiority on a lateralized nonsense word naming task that uses the same stimuli. There is also converging physiological evidence that the task requires left hemisphere resources (Shucard, Salamy, and Polson, 1982).

The second task involved remembering tones. Each trial consisted of the dichotic presentation of two single tones (one to each ear) followed by a single binaural tone. Right hemisphere trials were defined as those during which the subject was instructed to selectively attend to the left ear and respond on the basis of only the tone presented to that ear. Left hemisphere trials occurred when the subject was selectively attending to the tone presented to the right ear. The subject's task was to judge whether the dichotic tone presented to the attended ear and the following binaural tone were the same pitch. The tone task was chosen because it is similar to tasks used by other researchers who often find a right hemisphere (left ear) processing advantage in subjects who have little or no musical training (e.g., see Bever and Chiarillo, 1974; Gordon, 1980; Shucard, Shucard, and Thomas, 1977).

Thus, we felt we had two resource overlap situations depending on which ear is attended to. When the right ear is attended to, there should be complete overlap with the resources required to perform the tone task and the CVCVC memory task. In contrast, when the left ear is attended to, this should be a case of no overlap in the resource requirements of the two tasks.

Note that we are assuming that both hemispheres are capable of processing and remembering tones. It should be noted however, that the central auditory pathway involves both contralateral and ipsilateral connections, with each ear represented bilaterally up to the level of the medial geniculate body (Carpenter, 1976). However, physiological evidence from the work of Rosenzweig (1951; 1954) and Tunturi (1946) show that the contralateral auditory pathway is the fastest and strongest in terms in terms of amplitude of evoked cortical response to monaural stimuli. This is congruent with the observation that approximately sixty percent of the nerve fibers from one ear cross to the contralateral hemisphere and that the auditory cortex is primarily dominated by the fibers that cross (Rosenzweig, 1961).

Additional evidence of dominate representation of input from each ear to its contralateral hemisphere is given by studies of people who have had lesions or ablations to specific areas of the brain used for processing auditory stimuli. For example, Sinha (1959) studied patients with temporal lobectomies and found deficits in speech recognition when the speech was presented to the ear contralateral to the ablation. However, these deficits were only observed when the words were presented together with white noise to the ipsilateral ear, whereas in the absence of white noise no difference between the ipsilateral and contralateral ears was found. Jerger and Mier (1960) also reported speech perception deficits for the ear contralateral to a lesion of the auditory cortex, under conditions in which an irrelevant conversation was being channelled in the ipsilateral ear. Kimura (1961a; 1961b) has reported that the contralateral connections to the auditory cortex are more effective than the ipsilateral for processing verbal stimuli. Her studies reveal that patients with left temporal lobectomies show a large loss on discriminating digits presented to the ear contralateral to the lesion (right ear) but not for those presented to the ipsilateral (left) ear. Patients with right temporal lobectomies show a loss on the contralateral (left) ear and a slight gain on the ipsilateral (right) ear. Kimura's findings are consistent with those of Sinha (1959) and Jerger and Mier (1960) in showing that after temporal lobectomy, there is a selective impairment in the discrimination of stimuli presented to the contralateral ear.

When the evidence is considered together with other behavioral data using normal subjects (e.g., Gordon, 1980 Expt 1; Moray, 1970a; 1970b), it suggests that contralateral connections to the auditory cortex are stronger than ipsilateral connections and are the most vastly represented in the auditory cortex. Although there are ipsilateral connections to the hemispheres, these are considered to be weak and to transmit information much slower than the contralateral fibers. In fact, it is believed that the ipsilateral pathways may be primarily present to provide a mechanism for localization of auditory stimuli (Rosenzweig, 1951; 1954; 1961). Furthermore, it is apparent that during binaural or dichotic presentation, the ipsilateral pathways to the corresponding hemispheres are suppressed (Milner, Taylor, & Sperry, 1968; Sparks, Goodglass, & Nickel, 1970; Sparks and Geschwind, 1968) and that input is sent directly to the contralateral hemisphere. The ipsilateral signal does not appear to compete directly with the stronger contralateral input

In summary, based on the above findings and in accordance with the independent resources model, it is possible to identify which hemisphere is processing the tonal information during a dichotically presented selective tone matching task. When the left ear is selectively attended to, then information should be processed and remembered by the right hemisphere. Conversely, when the right ear is selectively attended to, the trials should require primarily left hemisphere resources. Note that the independent resources model assumes that both hemispheres can process and remember tones. In contrast, the functional cerebral distance model assumes that the tones are processed in a functional cerebral space that is located in the right hemisphere (Kinsbourne and Hicks, 1978).

According to the resources model, the combination of right and left ear tone task trials with the CVCVC memory load should constitute dual task situations that differ in degree to which left and right hemisphere resources are demanded. When the subject is attending to the right ear, there should be complete overlap in resource demand of the CVCVC and tone tasks, as they both require left hemisphere resources. Left-ear dual task trials should constitute a situation of no overlap in resource demand, since the CVCVC memory task requires left hemisphere resources whereas the tone task requires right hemisphere resources. Since the task to be performed and the stimuli used are identical regardless of the ear to which the subject is attending, differential decrements or tradeoffs between the hemispheres cannot be attributed to the nature of the tone task per se.

Therefore, when subjects are attending to the left ear (i.e., when the right hemisphere is processing the relevant dichotic tone), there should be no single-to-dual task decrements because the CVCVC memory and tone tasks are hypothesized to require resources from different, and independent, pools. Futhermore, task performance levels should not be mutually altered by shifts in attentional resource allocation (e.g., there should be no mutual trade-offs between tasks). On right ear-left hemisphere trials, however, the model predicts single-to-dual performance decrements for both tasks as well as trade-offs, since the resource demands of the CVCVC memory and tone tasks should overlap completely.

In contrast, the single capacity model predicts there will be similar single-to-dual performance decrements and tradeoffs for both CVCVC memory-tone task combinations. This is based on the assumption that all of the resource demands are believed to be on the same (and only) resource pool, and thus, resources should be equally accessible and allocatable to the tasks regardless of the ear to which the subject is attending.

An alternative single capacity model could be postulated if it is assumed that resources are not strictly allocated according to the experimentally defined allocation policy. For example, if resource allocation varies with task difficulty, then more resources may be allocated to perform a task when it is perceived to be difficult than when it is perceived to be easy. Since subjects typically show a right hemisphere (left ear) advantage for processing tones, right ear tone trials might be more difficult than left ear trials. Consequently, more resources may be allocated to the tone task during right ear trials than during left ear trials. This interpretation leads to single capacity predictions of greater CVCVC memory task decrements during right ear than during left ear trials. However, the assumption that the more difficult of two tasks is allocated more resources irrespective of experimental allocation policies is not congruent with past empirical evidence (e.g., see Briggs, 1975; Friedman, Polson, Dafoe, & Gaskill, 1983; Hicks, 1975; Kinsbourne & Cook, 1971; Kinsbourne & Feign, 1978). For example, if relative difficulty is assessed by single task performance, as implied above, then in a situation where subjects were to attend equally to two tasks, Kinsbourne and Cook (1971) found decrements when a verbal task was combined with an easy (right hand trials) but not a difficult (left hand trials) dowel balancing task. Similarily, Friedman et al. (1982) found performance decrements when a CVCVC memory task was combined with an easy (right visual field trials) but not a difficult (left visual field trials) nonsense word naming task, and importantly, they found that when subjects were paid to allocate more attention to one of the tasks, that performance tradeoffs only occurred during the easy nonsense word naming trials. These studies suggest that resources are allocated according to experimentally defined allocation policies, and that subjects do not differentially allocate resources depending on task difficulty. Therefore, consideration will hereinafter be given to only the single capacity model and the corresponding predictions that were presented earlier, and resource allocation will be discussed only as it applies to experimentally defined allocation policy.

The predictions of the functional cerebral distance model would be the same as with the single capacity model.

According to the functional cerebral distance model, the CVCVC and tone tasks are assumed to be processed in the left and right hemispheres, respectively. This is believed to be the case despite shifts in selective attention from one ear to the other. Therefore, if there are single-to-dual task performance decrements and trade-offs, they are predicted to be similar for both CVCVC-tone combinations.

Alternative predictions are possible if the functional cerebral distance model is interpreted differently, for example, if it is assumed that left and right ear trials require different cerebral networks. However, such an assumption is difficult to accept, since each tone task trial consists of presentation of the tones to both ears, and in Kinsbourne's sense of "categorical similarity," the task does not change between left and right ear attended trials.

For the purposes of the present study and the corresponding theoretical implications, it is important to confirm empirically that subjects are capable of selectively attending to one ear in a dichotic or a binaural presentation. Moray (1970a; 1970b) found that subjects are generally more accurate when they are required to selectively attend than when they must divide their attention between both ears. In these studies, subjects were better able to detect frequency (as well as loudness) changes between two sets of dichotically presented tones if they attended to and detected changes in only one ear, rather than if they had to listen to both ears. This, of course, does not suggest that subjects totally ignore the tones presented to the unattended ear, but it does suggest that they are able to do, so at least to the extent that performance is superior to that of listening to both ears.

In the present study, an experimental control session was run to determine the extent to which the tone presented to the unattended ear is processed. Two conditions were used that differed only in what occurred during trials when the binaural and attended tones did not match (e.g., the "no" trials). These are called the "pure" and "mixed" conditions. The pure condition was identical to the tone task used in the main experiment (e.g., the binaural tone did not match either of the two dichotic tones). However, in the mixed condition, while half the "no" trials were the same as the "no" trials in the pure condition, the others differed in that the binaural tone matched the dichotic tone presented to the <u>unattended</u> ear.

If processing the unattended tone occurs regardless of efforts to ignore that tone, then it may be confused with the tone presented to the attended ear. In such a case, there would be greater chance of confusion between the unattended and attended tones during the mixed condition in which the unattended and binaural tone match. However, if the unattended tone is not processed to the extent that it competes with the attended tone, then no differences in performance between the pure and mixed conditions should occur.

II. METHOD

The experiment took place across three days. Day 1 consisted of a screening session and a practice session. Day 2 consisted of the experimental session, and Day 3 the experimental control session.

Subjects

Eight right-handed males from the University of Alberta who met the selection criteria outlined below participated in the main experiment. All used a non-inverted writing posture (Levy and Reid, 1976; 1978), had normal or corrected to normal vision, non-impaired hearing, and spoke English as their native language. None had any familial history of left handedness (Hardyck and Petrinovich, 1977).

Subject Screening and Practice

Testing the resource pool approach requires accurate assessment of the resource requirements of the tasks for the particular subjects tested. To achieve this, we used only those subjects whose single task performance was congruent with the assumptions we made about the resource requirements of the CVCVC memory and tone tasks.

Subject screening took place in a series of stages, and subjects who did not meet the criterion at each successive stage did not participate further. Subjects first filled out a behaviorally-validated handedness questionnaire that asked 15 questions about manual ability (Raczowski, Kalat, and Nebes, 1974). The response choices were right, left, or both hands equally capable, which were scored as 1, -1, or 0 respectively. Of the 25 volunteers who answered the questionnaire, 19 (76.0%) reached the criterion score of 12 or more, and these men went on to perform a task to screen for left hemisphere processing of CVCVC's.

CVCVC Memory Task Screening. Subjects who showed a right visual field processing advantage of at least 10% for naming CVCVC's were assumed to require primarily left hemisphere resources for the CVCVC memory task. There were 60 trials of CVCVC naming (10 practice and 50 experimental), with half the stimuli presented to each visual field. The order of presentation was random, with no more that five in a row presented to one side. The stimuli were centered vertically, 3 degrees from fixation, and subtended a vertical angle of 3.8 degrees. All stimuli were exposed for 130 msec. To familiarize the subjects with the pronounciation of the 60 nonsense words, they were required to read them aloud before the task began.

Of the 19 subjects screened on the visual task, 14 (73.7%) met the 10% right visual field advantage criterion. The left and right visual field percentage correct for these 14 subjects was 45.1% and 80.0%, respectively, $\underline{t}(13) = 6.81$, $\underline{p} < .001$. In contrast, the left left and right visual field performance for the five subjects who were disqualified was 67.2% and 63.2%, respectively, $\underline{t}(4) = 1.07$, $\underline{p} > .20$.

Eight of the 14 subjects (57.1%) who passed the visual field screening test also passed the tone memory test, and went on to participate in the main experiment. The average left and right visual field performance for these eight subjects was 44.0% and 77.5%, respectively, $\underline{t}(7) = 5.42$, $\underline{p}$

<.001.

Tone Memory Screening. Fourteen subjects performed 24 tone memory trials (4 practice and 20 experimental) attending with each ear, starting with the left ear and finishing with the right ear. Note that if subjects improved with practice, the order of testing biases against obtaining a left ear superiority.

For practice trials, the subject was first informed whether the trial was a matching (e.g., the attended ear tones matched) or a non-matching (e.g., the attended ear tones did not match) trial. During the screening trials, feedback was provided immediately following the subject's response. Since the task was the same as the tone task used in the following experimental day, subjects were paid during this session just as they would be in the experimental day. In this way, the screening session also served as practice for single-task tone trials. Subjects received feedback after each trial, and were able to earn up to two dollars for their performance. If the subject's response was correct (i.e., hit or correct rejection), it was indicated on the CRT that five cents had been earned for that trial. If the response was incorrect (i.e., miss or false alarm), it was indicated that no money had been earned for that trial.

Of the 14 subjects who performed this screening task, eight (57.1%) met the criterion of at least a 10% left ear processing superiority. For these subjects, left ear performance ranged between 65% to 95% correct, and right ear performance between 55% and 85% correct. The average left and right ear performance was 82.5%, s.d. = 9.64, and 70.6%, s.d. = 10.50, respectively, <u>t</u>(7) = 6.33, <u>p</u> <.001. In contrast, for the 6 subjects who did not meet the criterion, the left and right ear performance was 59.2% and 64.2%, respectively, <u>t</u>(5) = 1.58, <u>p</u> >.10.

Practice. If a subject passed all three screening tasks he was asked to participate further, and the remainder of Day 1 was used for practice on the CVCVC memory and dual-task trials. Monetary rewards were given to the subjects for their performance during the practice session on a trial-by-trial basis. The payoff scheme was identical to that used later in the experimental day. The previous 48 tone task trials served as the practice trials for that task. There were 24 CVCVC memory and 48 dual-task practice trials.

The CVCVC practice and experimental trials were identical, except that during the practice session the subject received immediate feedback concerning his performance on a trial-by-trial basis.

The dual-task practice trials were divided into the emphasis (CVCVC emphasis vs. tone emphasis) by ear (left ear attended vs. right ear attended) conditions, with twelve trials per condition.

<u>Design</u>

The main experiment used a two (CVCVC memory task vs. tone memory task) by two (right ear attended vs. left ear attended) by two (CVCVC emphasis vs. tone emphasis) within-subjects design. Order of task emphasis and which ear was attended to first were counterbalanced across subjects.

Subjects received two sets of conditions, consisting of one block each of single task CVCVC and tone task trials, and one block of dual task (CVCVC or tone emphasis) trials. Baseline performance levels were obtained by yoking single task trials with corresponding dual task conditions.

Each block of single and dual task trials was preceded by a practice set. For each emphasis condition, subjects received 24 single task CVCVC memory trials (4 practice and 20 experimental), 48 single task tone trials (4 practice and 20 experimental per ear), and 48 dual task trials (4 practice and 20 experimental per ear). Within each emphasis condition, half the single-task and dual-task tone trials were right hemisphere trials (left ear attended) while the other half were left hemisphere trials (right ear attended). Half the subjects began both single and dual task trials by attending to their left ears and the other half began by attending to their right ears. Half of each of these groups received the CVCVC task emphasis set of trials first, and the other half received the tone task emphasis trials first.

Subjects were paid on the basis of trial-by-trial performance to induce them to allocate their resources to the tasks differentially. On single task CVCVC trials, they received five cents for correct recall of all three nonsense words, with order of recall disregarded. On single task tone trials, they were paid five cents for a correct response (e.g., hit or correct rejection).

Dual task performance was rewarded according to the emphasis condition. For CVCVC emphasis trials, four cents was paid for correct recall of all three nonsense words and one cent for a correct tone task response. On tone task emphasis trials, the reverse contingency was in effect. Subjects were given feedback at the end of each block of trials regarding how much they had earned on each task. In total, subjects had the opportunity to earn up to ten dollars for participating in the experimental session. The average amount earned was $5.35.

Procedure

The timing parameters for the various conditions are outlined in Figure 2. On single-task CVCVC memory trials, the experimenter sounded a warning "click" that was followed 500 msec later by the appearance of the three CVCVCs. These stayed on the screen for 2.5 sec, during which time the subject was to say them aloud. After the nonsense words disappeared, there was a 5.5 sec pause and then a second "click" was sounded that was a signal to begin recall.

Each single-task tone trial consisted of a warning "click" followed half a second later by a pattern consisting of a three by four matrix of dots that appeared on the CRT. The matrix was on the screen for 2.5 sec, during which time the subject was merely to look at the pattern. The pattern was presented to simulate the procedure that would be used on the dual-task trials. Half a second after the pattern disappeared, two single tones (one to each ear) were

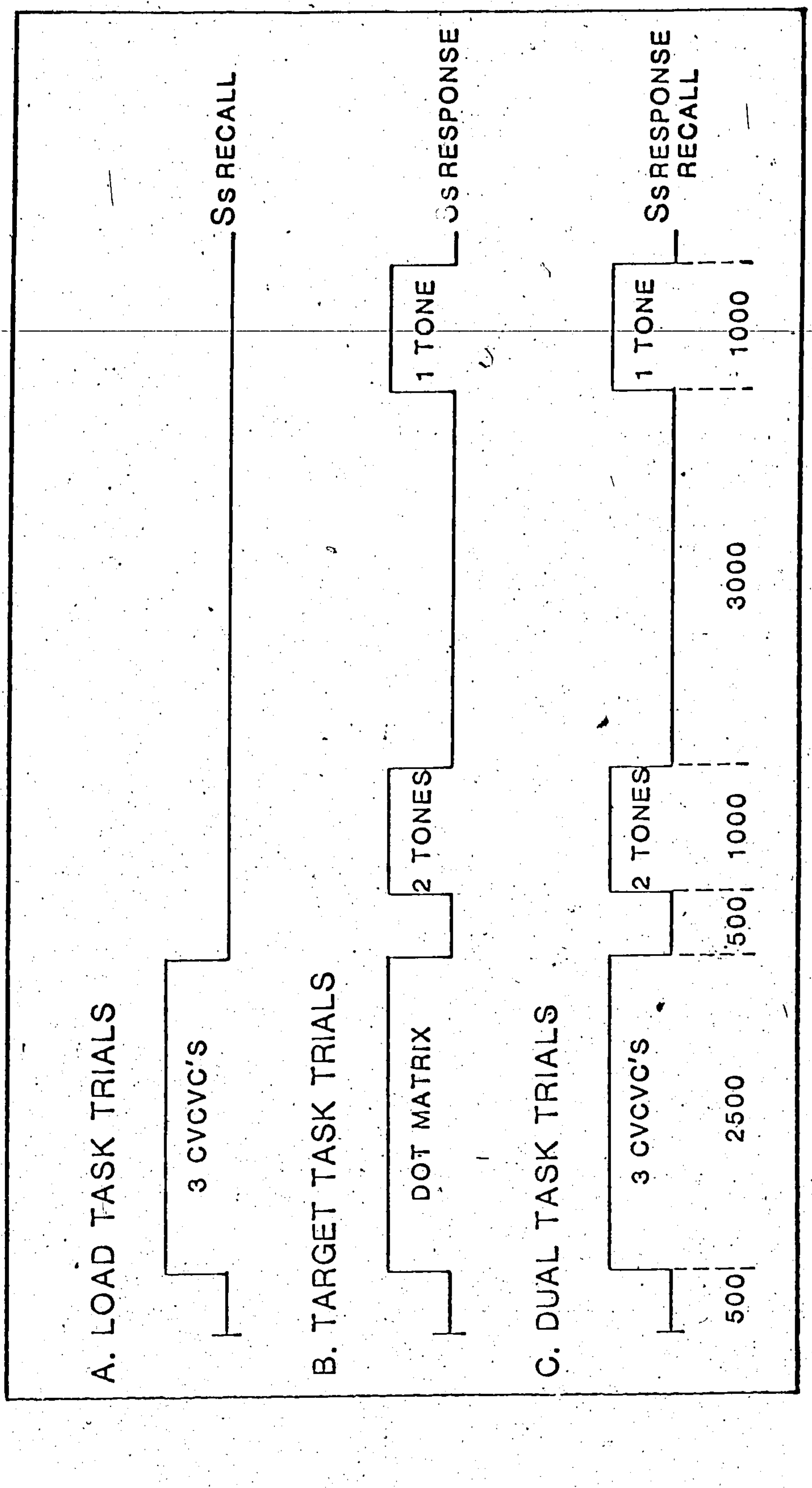

Figure 2. Timing parameters for the CVCVC memory, tone memory, and dual task conditions.

presented for one sec. These were followed by a three sec pause, and then by a one sec binaural presentation of a single tone. The subject was required to listen selectively to only one ear and to indicate with a bimanual response whether the tones presented to that ear matched in pitch (Hz). Index fingers were used for a matching response and middle fingers for a nonmatching response.

The dual-task trials involved presenting a warning click that was followed 500 msec later by the three CVCVCs. These remained on for 2.5 seconds, during which time the subject said them aloud. The tone task began 500 msec after the words disappeared. The subject was instructed to hold the CVCVC items in memory while performing the tone task. Once the subject had indicated whether or not the dichotic and binaural tones presented to the attended ear matched in frequency, he was to recall out loud the three CVCVCs that were held in memory.

Stimulus Materials

Sixty two-syllable nonsense words for the CVCVC task screening session and 432 for the CVCVC memory task were drawn from a pool of CVCVCs. This pool was created with a computer program in which all letters except Y and Q were used. A paid research assistant screened the words and discarded any that were not pronouncable or that had high associations. Each of the nonsense words appeared only once in the experiment, so there was no opportunity for subjects to become familiar with them.

There were a total of 24 sets of tones for the experimental day, ranging in frequency from 440 - 900 Hz. These are listed in Appendix A. Half the dichotic tones presented to the unattended ear were one musical step higher in frequency than the tone presented to the attended ear and half were one musical step lower. Half of the following binaural tones matched the tone presented to the attended ear and half did not. The non-matching binaural tones were above and below the attended and unattended tones an equal amount of time, by one and a half musical steps. The binaural tone never matched the dichotic tone presented to the unattended ear.

Five groupings of the 24 tone sets were used, each with a different order of stimuli. One grouping was always used during the practice session. The remaining four were presented in each of the four emphasis-order by ear-order conditions. Two orders of presentation were devised such that if one group of 24 sets of tones preceded another in the single-to-dual task conditions, then this order was reversed for another subject. The target task tones were recorded ~~directly from~~ two Texas Instrument Model 99/4 computers (one per channel) using a SONY TC-K777 Stereo Cassette Deck and SONY EHF C2O2 tape.

Apparatus

The stimuli for the lateralized screening task were shown using a Kodak Carousel projector equipped with a Gerbrand's shutter. The projector was located on a stand outside the experimental room. The images were displayed through two half-silvered mirrors and a glass window onto a rear projection screen. A Digital Equipment MINC/11 computer, also located outside the experimental room, was used to control the equipment and timing intervals. The computer was also connected to a Hazeltine 1510 CRT that displayed the CVCVCs. The subject was seated in front of the CRT, approximately 98 cm from the rear projection screen.

The Sony tape recorder was interfaced to the computer to allow for precise real time control. The arrangement was such that the computer started and stopped the tape as well as monitored for the presence and absence of a tone. The target stimuli were presented to the subject over Sony DR-S3 Dynamic stereo headphones. The attended channel was always presented over the same headphone output. When the tone task condition changed the headphones were reversed so that the proper channel was being presented to the attended ear. Also, the same recording was used for both the left and the right hemisphere presentations within a block. A Bruel and Kjaer artificial ear was used to measure and set the headphone outputs to 60 db. The experimenter used a remote control unit connected to the tape recorder to advance or rewind the tape containing the tones.

The subject responded to the tone task using two response boards, each consisting of a metal palm plate, two metal finger plates (for the index and middle fingers of each hand), and two strips of wood 1.8 cm high between the finger plates. The subject rested his fingers on the wooden strips between trials, and touched the finger plates in order to respond. The subject touched both index fingers to the plates to indicate that the attended ear tones matched in pitch. The middle fingers were to be used to indicate a non-matching judgement.

Experimental Control Session

This session was conducted after the experimental day. Subjects were given monetary rewards for their performance according to the single tone task payoff scheme outlined earlier. The timing parameters and experimental procedure were identical to those used in the single-task tone memory trials of the main experiment.

Design. The control experiment was a two (right vs. left ear attended) by two (pure condition vs. mixed condition) design. There were 144 trials divided equally into three blocks. One block consisted of the pure condition trials and the other two blocks contained the mixed condition trials. Within each block, half the trials were left ear attended trials and the other half were right ear attended trials. Half the subjects began with left ear trials and the other half with right ear trials. Half of each of these groups received the pure condition first followed by the two blocks of the mixed condition, and the other half received the opposite order.

In all blocks, the first four trials were practice. In the pure condition, there were therefore 24 "yes" trials per ear in which the binaural tone matched the tone in the attended ear and 24 "no" trials in which the binaural tone matched neither the attended nor unattended tone. In each block of the mixed condition, there were also 24 "yes" trials, but on half the "no" trials the binaural tone matched the tone in the unattended ear, and on half it did not. The two types of trials were presented randomly throughout the block. Thus, across the two mixed blocks, there were as many pure and mixed "no" trials (i.e., 24) per ear as there were in the single block of pure trials.

Stimulus Materials. The same tone stimuli that were used in the main experiment were used in the pure condition. The mixed condition differed in that half the nonmatching stimulus sets were altered so that the binaural tone was the same pitch as the unattended tone. Half of these were higher than the attended tone and half were lower. (The stimulus sets are also shown in Appendix A.)

III. RESULTS

The tone task data were scored separately for each type of trial (left vs. right ear attended). The number of correct responses (hits plus correct rejections) was divided by the total number of trials presented per condition and expressed as percentages. The CVCVC memory data were scored by dividing the number of words correctly recalled by the total number of words presented, also expressed as percentages. For each of the two emphasis conditions, the dual-task tone and CVCVC data were scored separately for the two types of tone trials (left vs. right ear attended) within an emphasis condition.

Since the tone task was a "yes-no" recognition task, the use of signal detection theory to determine recognition sensitivity and response criterion was considered. However, the tone task data were not conducive to interpretation within a detection theory framework for two reasons. First, detection theory is based on the assumption that the observer is not perfect and thus, will make errors. In the obtained tone data, 53% of the data contained either false alarm rates equal to 0.0% or hit rates of 100%. For these instances, d' and beta cannot be calculated.

Second, it was necessary to be able to put both the CVCVC and tone task data on a common scale, so that mutual performance changes on these two tasks could be compared. Since the CVCVC data did not include recording of intrusion errors (e.g., false alarms), it was not possible to convert it to the signal detection scale. Consequently, the main data to be discussed will be percent correct scores for both tasks.

Experimental Day

Three basic analyses will be discussed. The first involves single-task performance on both the CVCVC and tone tasks. This serves as a baseline against which absolute dual-task performance can be compared. The second set of analyses is concerned with the dual-task conditions. This was used to compare the major variables of interest in terms of absolute performance measures (e.g., percent correct). The last set of analyses involves single-task to dual-task differences. These were used to assess the amount of performance decrement as well as the performance trade-offs between the CVCVC and tone task. To obtain decrement scores, each subject's dual-task performance (expressed as percent correct) was subtracted from the appropriate single-task control block. The mean single-task, dual-task, and single-task to dual-task data are shown in Appendix B.

Some researchers have used relative percent decrements (e.g., (single task - dual task)/single task) instead of pure percent decrements. The advantage of using relative percentages is that they equate subject performance levels in that performance is expressed with respect to single-task baselines. With a pure percent measure, a decrement of 10 units represents an equal amount of performance change, regardless of the baseline performance level. However, with relative percent measures, a 10 unit change represents a larger decrement when compared to lower than a higher baseline.

In the present analysis it was decided to discuss only pure percent decrements, because they tend to be more conservative. However, the data were also analyzed using relative percent decrements. These two approaches yielded identical results, except that the relative percent decrements tended to give larger differences between means.

Single-Task Performance

CVCVC memory task. There were 20 CVCVC memory trials for each of the two single-task blocks. The data were analyzed in a one-way ANOVA with block as the only factor. There was no difference between the two blocks (Block 1 = 54.4%, Block 2 = 53.7%). Therefore, we can assume that the CVCVC memory baseline performance level remained constant across conditions and throughout the experimental day.

Tone task. The single-task tone data were analyzed in a 2 (left ear trials vs. right ear trials) by 2 (Block 1 vs. Block 2) ANOVA. The main effect of ear attended to was not reliable (73.8% vs. 72.5%, respectively for the left and right ear), and performance did not change across blocks (Block 1 = 75.6%, Block 2 = 70.6%). A non-significant interaction indicated that the performance levels remained constant across blocks regardless of which ear was attended on the target task.

It is of some interest to note that the original left ear processing advantage on the tone task (the basis on which subjects were selected during the screening day) disappeared in the experimental session. However, it should be noted that this does not change the predictions of the independent hemisphere resources model, since the assumed resource overlap or lack of it remains the same (see Friedman, Polson, Dafoe, and Gaskill, 1982, Expt.2).

Dual-Task Performance

The means for the various dual-task conditions are presented in Figure 3. Each point on the figure is based on a maximum of 20 trials. An ear (left vs. right) by task emphasis (CVCVC vs. tone) by task (CVCVC vs. tone) ANOVA indicated that left (57.2%) and right ear (55.6%) trials did not differ reliably, nor did the CVCVC (56.9%) and tone emphasis (56.0%) conditions. However, there was a reliable effect of task, indicating that subjects performed better on the tone (71.4%) than on the CVCVC task (41.5%). There were no reliable interactions.

The CVCVC and tone task data were also analyzed in separate ANOVAs in which the factors were task emphasis (CVCVC vs. tone) and type of tone trial (left ear attended vs. right ear attended). The analysis of the CVCVC task indicated that recall did not differ between left ear (42.0%) and right ear (40.9%) tone task conditions. In addition, the two emphasis conditions did not yield differential recall (CVCVC emphasis = 43.1%, tone emphasis = 39.8%). However, there was a significant interaction between attended ear and emphasis, $\underline{F}(1, 7) = 6.63$, $\underline{p} < .037$. F-tests for the simple effect of emphasis for each ear condition show that while recall did not vary between emmphasis conditions during left ear trials (CVCVC emphasis

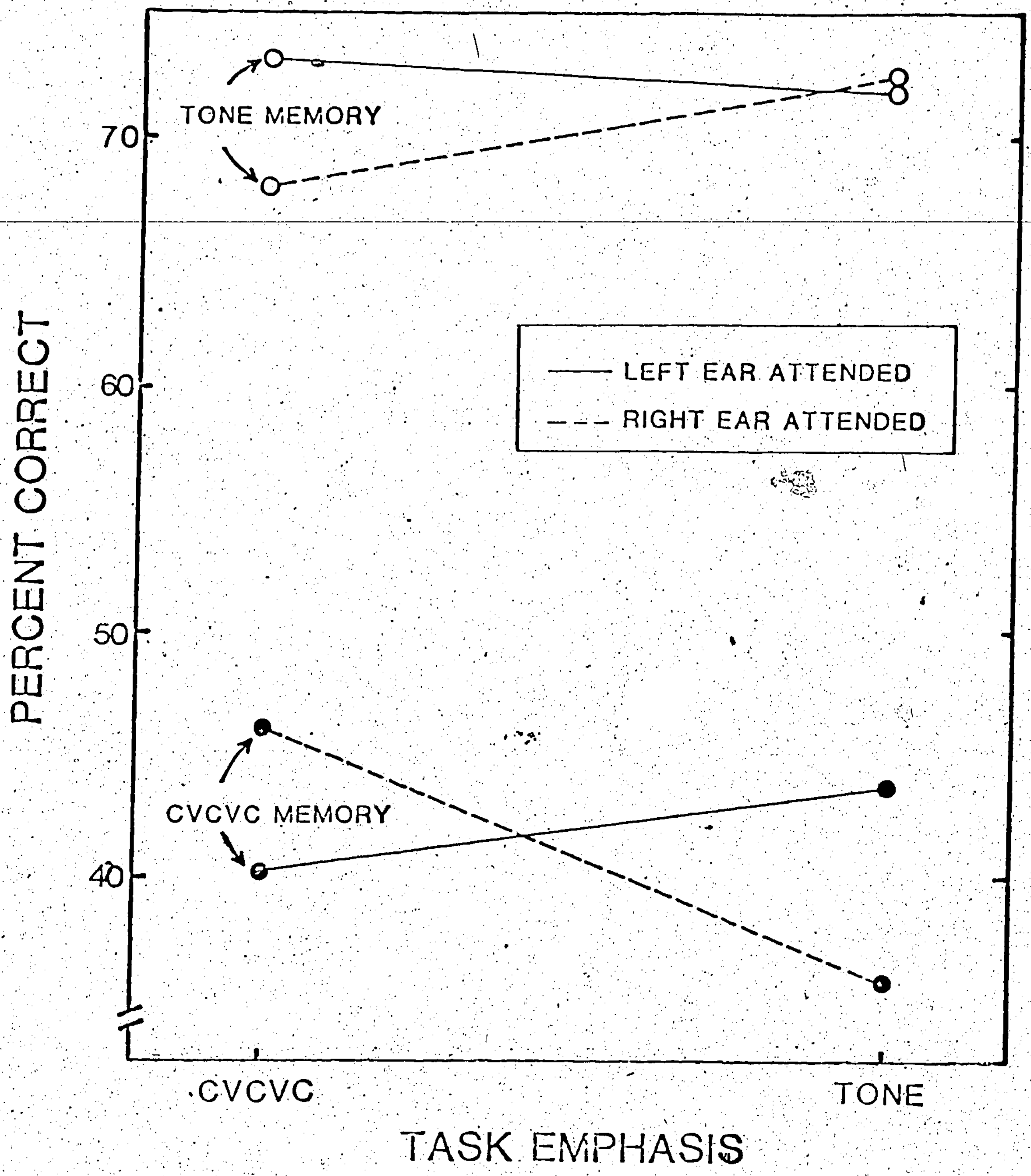

Figure 3. Percent correct on the CVCVC and tone memory tasks.

= 40.2%, tone emphasis = 43.8%), for right ear trials there was more recall during CVCVC emphasis (46.1%) than during tone emphasis (35.8%), F(1,7) = 7.42, p <.05. Therefore, performance on the centrally presented CVCVC task was differentially affected by both the emphasis condition and the particular ear being attended to.

For the tone task, left ear trials (72.5%) were not reliably more accurate than right ear trials (70.3%), nor was the percent correct significantly different during CVCVC (70.63%) and tone emphasis (72.19%) conditions. Furthermore, the emphasis by ear interaction was unreliable, indicating that for these absolute percent scores, the emphasis manipulation did not yield different tone task performance on left vs. right ear trials (see Figure 3). Note, however, that there is little indication that performance is trading during left ear trials (CVCVC emphasis = 73.1%, tone emphasis = 71.9%), whereas the effect is in the expected direction on right ear trials (CVCVC emphasis = 68.1%, tone emphasis = 72.5%). The lack of significance using absolute percent correct scores is not surprising, since these do not take into consideration individual differences in baseline performances (recall that there are two baseline blocks per subject, each yoked to its corresponding dual-task condition).

Single-to-Dual Task Decrements

The most interesting analyses for the independent resources theory are those involving single-to-dual task performance decrements. The CVCVC and tone task decrement data are presented in Figure 4. A task emphasis (CVCVC vs. tone) by ear attended to (left vs. right ear) by task (CVCVC vs. tone) ANOVA yielded a reliable three-way interaction, $F(1, 7) = 6.108$, $p < 0.043$. The means for this interaction (see Figure 4), suggest that differential performance decrements and trade-offs on both tasks only occurred during right ear attended trials. To test this, F-tests for the simple effect of emphasis were performed for each task and ear condition. Whereas a change in emphasis did not affect tone task performance on left ear trials (CVCVC emphasis = 2.5% decrement, tone emphasis = 0.0% decrement), it did affect tone task performance on right ear trials, $F(1, 7) = 5.82$, $p < .05$, so that performance decremented more during CVCVC emphasis (7.5%) than during tone emphasis (-3.1%). Futhermore, CVCVC task performance during left ear trials was also unaffected by the emphasis manipulation (CVCVC emphasis = 13.3% decrement, tone emphasis = 10.8% decrement), whereas CVCVC task performance during right ear trials decremented more when the tone task was emphasized (18.7%) than during CVCVC emphasis (7.6%), $F(1, 7) = 6.39$, $p < .05$. These analyses show that there were performance trade-offs only when left hemisphere resources were demanded by both the CVCVC and tone tasks; that is, when subjects were responding on the basis of the tone presented to the right ear.

Individual t-tests on the decrement scores were used to determine which of the dual-task conditions were significantly different from the baseline levels. On left

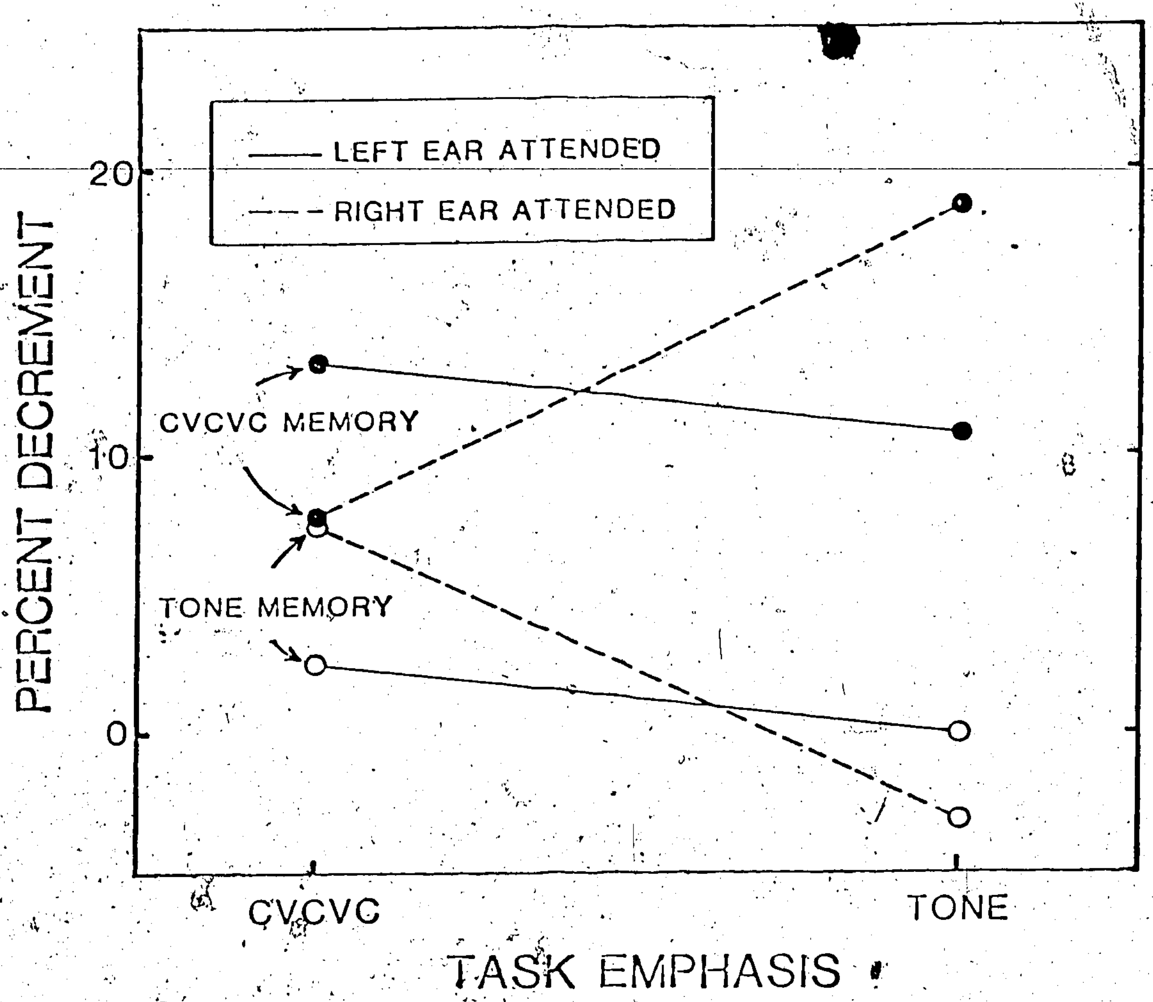

Figure 4. Percent single-to-dual task performance decrements for the CVCVC and tone memory tasks.

ear trials, the CVCVC task decrements were reliably different from zero for both CVCVC and tone emphasis conditions ($t(7) = 2.75$, $p < .05$ and $t(7) = 2.65$, $p < .05$, respectively). However, left ear tone task decrements were not reliably different from zero for either emphasis condition.

For right ear trials, the CVCVC task decrements were reliable during tone task emphasis ($t(7) = 3.79$, $p < .01$) but only approached reliability during CVCVC task emphasis ($t(7) = 2.29$, $p < .06$). The tone task decrements were also not reliable, although decrements during CVCVC emphasis did approach significance ($t(7) = 2.29$, $p < .06$).

Separate task by emphasis analyses were performed for each ear condition to ensure that there were differential task emphasis effects on the CVCVC and tone tasks only during right ear tone task trials. On left ear trials neither the main effects nor the interaction was reliable. In contrast, on right ear trials there was a significant Task X Emphasis interaction $F(1, 7) = 6.37$, $p < .04$. Thus, there were performance trade-offs between tasks with a change in task emphasis when both tasks were competing for left hemisphere resources.

Control Experiment

An analysis of the overall percent correct data (i.e., hits plus correct rejections) was performed to compare the pure condition control session performance to performance on the main experimental session in single-task tone trials. The experimental session scores were derived by averaging scores obtained on the two single-task blocks. Left ear (71.5%) and right ear (70.9%) performance did not reliably differ, and the control (69.3%) and experimental session (73.1%) performance was also not reliably different. Futhermore, there was no interaction between ear and session. Left ear performance averaged 73.8% and 69.3%, and right ear performance averaged 72.5% and 69.3%, for the experimental and control sessions, respectively. This analysis indicates that the subjects performed similarly in the control and experimental sessions during comparable conditions.

An analysis comparing percent correct on the two different types of control session conditions (e.g., pure vs. mixed) indicated subjects were more accurate on left ear trials (68.1%) than on right ear trials (61.6%), $\underline{F}(1, 7) = 8.18$, $\underline{p} < .024$, and they were also more accurate during the pure block (69.3%) than during the mixed block (60.4%), $\underline{F}(1, 7) = 18.23$, $\underline{p} < .004$. Futhermore, there was a significant interaction between ear and condition, $\underline{F} = 7.30$, $\underline{p} < .031$. Whereas the left ear performance did not differ as a function of condition, (pure = 69.3%, mixed = 66.9%), right ear performance dropped from 69.3% in the pure condition to 53.9% in the mixed condition. This suggests that subjects were better able to attend selectively during left ear trials than during right ear trials.

To determine the locus of the performance decrements during the mixed blocks, relative to the pure block, the hit and false alarm rates were analyzed separately. The hit rate analysis did not yield reliable differences for left vs. right ear trials (78.4% and 73.4%, respectively), or for type of block (pure = 80.7%, mixed = 71.1%, respectively), although the latter approached reliability, $\underline{F}(1,7) = 5.12$, $\underline{p} < .06$. However, the ear by condition interaction was not reliable, indicating that the hit rates did not differ as a function of which ear was being attended to (the hit rates in the pure vs. mixed blocks were 81.3% and 75.5% for the left ear trials, respectively, and were 80.2% and 66.7% during the right ear trials).

Planned comparisons were performed on the false alarm data (see Figure 5) in order to analyze the interaction between ear and type of "no" trial. There were three types of "no" trials; pure and non-matching "no" trials (i.e., when the unattended tone and the binaural tone were different) and matching "no" trials (i.e., when the unattended tone matched the binaural tone).

The interaction of ear and non-matching vs. matching trials was found to be reliable, $\underline{F}(1,14) = 12.87$, $\underline{p} <.01$. The means indicate that while the false alarm rates increased only slightly from non-matching to matching trials when the left ear was attended to (36.5% and 46.9%, respectively), there was a large increase in the false alarm rate when the right ear was attended to (47.9% and 69.8%, for pure and mixed "no" trials, respectively). This interaction suggests that the unattended tone was confused with the attended tone; subjects incorrectly indicated that the trial was a "yes" trial, especially when they were attending to their right ears.

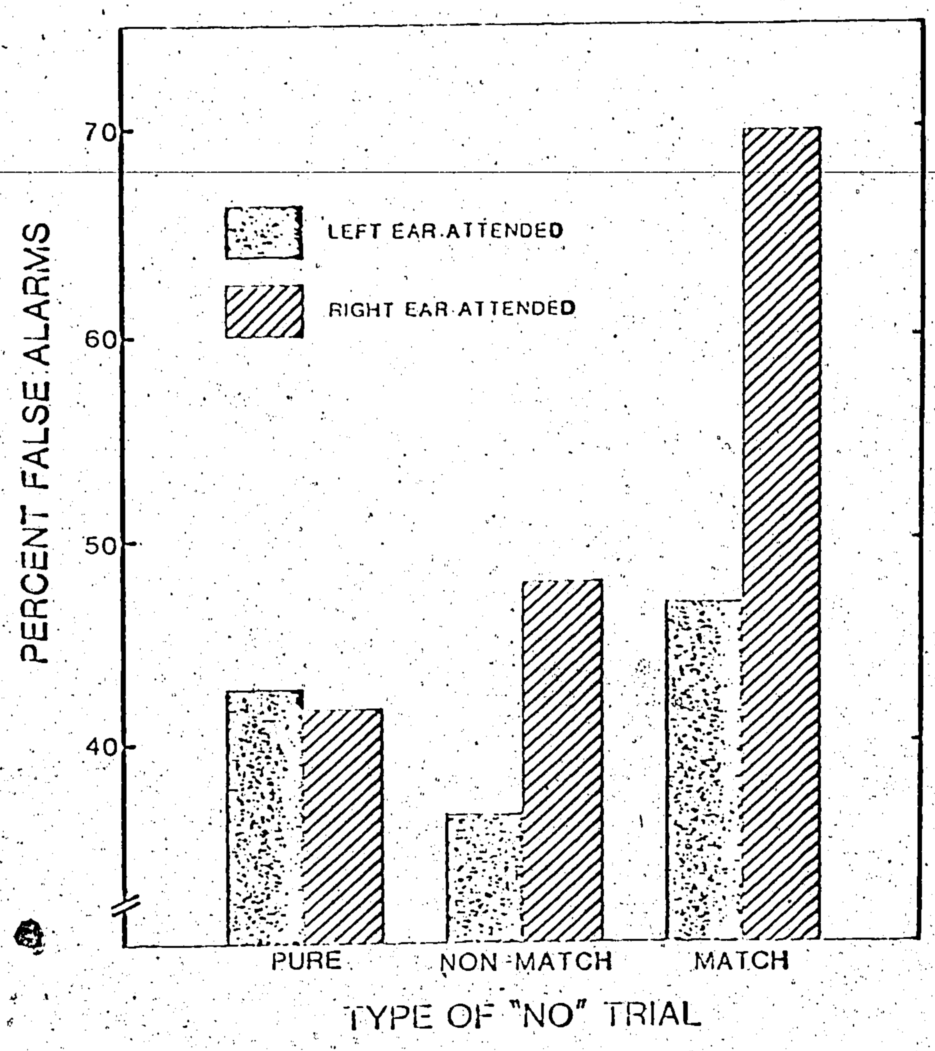

Figure 5. Percent false alarms for the pure, non-matching, and matching conditions: experimental control session.

A second comparison was made on the interaction between ear and pure vs. non-matching "no" trials during the mixed blocks. It was expected that this interaction would not be significant since the stimuli were the same for both the pure and non-matching trials. However, a reliable effect was obtained, $\underline{F}(1,14) = 7.96$, $\underline{p} < .05$. The means show that during left ear trials, the false alarm rate decreased from pure (42.7%) to non-matching (36.5%) trials, whereas during right ear trials there was a slight increase from pure (41.7%) to non-matching (47.9%) trials. Therefore, the presence of some factor during the mixed blocks of trials which caused the subjects to respond differently from the pure block must be considered. This factor differentially affected performance, depending on which ear was being attended to. However, it should be noted that when subjects were attending to the right ear on matching trials, the false alarm rates were still 21.9% above the false alarm rates for the non-matching trials. Thus, even if the mixed condition produced some general strategy changes across all types of trials (including hits), those trials most severely affected were those when the subject was trying to ignore a tone presented to the left ear that happened to match the attended tone.

A third analysis was performed on the interaction between ear and pure vs. matching trials. This comparison is similar to the analysis of ear and non-matching vs. matching trials that was presented earlier, but was included since it is difficult to determine whether performance during pure or non-matching trials should be used as a baseline from which to contrast the matching trial performance. The interaction was found to be reliable, $F(1,14) = 20.83$. $p < .001$, and the means once again indicate that there was a larger increase in false alarms during right ear trials (pure = 41.7%, matching = 69.8%) than during left ear trials (pure = 42.7%, matching = 46.9%). This supports the conclusion made earlier that the unattended tone was confused with the attended tone, and that this occurred especially during right ear trials.

In summary, the decrease in hits from the pure to the mixed conditions suggests that subjects may have adopted a more conservative strategy during the mixed blocks of trials. The false alarm data show that during matching trials the unattended tone was confused with the attended tone. The significant interaction of ear and type of trial, using either pure or non-matching "no" trial performance as baselines from which to compare the matching "no" trial performance, indicate that during right ear attended trials, the unattended tone was being confused with the attended tone. This effect appears to be beyond the influence of general response strategies that may have been adopted by the subjects during the mixed condition.

IV. DISCUSSION

The main experiment involved combining two tasks so that different overlapping resource demand situations could be examined. A CVCVC memory task that required left hemisphere resources was paired with a tone memory task that required either left or right hemisphere resources, depending on which ear was being attended to. The independent resources model predicted different single-to-dual task decrements and differential effects of task emphasis as a function of differences in assumed resource overlap on right vs. left ear-attended trials. On left-ear trials there was presumed to be no overlap in demand between the CVCVC and tone tasks, whereas on right-ear trials there was presumed to be complete overlap in demand. In contrast, a single capacity model should assume that the same resources were demanded regardless of the ear being attended. Consequently, the single capacity model predicted similar single-to-dual task decrements and equivalent effects of task emphasis for both left and right-ear attended tone trials when combined with the CVCVC memory task.

The results are more supportive of the independent resources model than they are of the single capacity model. On right-ear tone trials, CVCVC task performance decremented more during tone emphasis than during CVCVC task emphasis. Conversely, tone task performance decremented more during CVCVC task emphasis than during tone task emphasis. Thus, on the trials when complete overlap was presumed to exist, there were mutual trade-offs between tasks. On left-ear tone trials, however, although performance on the CVCVC memory task decremented significantly from baseline levels, it did not vary with shifts in task emphasis. In addition, tone task performance neither decremented from baseline nor fluctuated with task emphasis, which supports the idea that there was no overlap in demand when the left ear was being attended to.

Three assumptions of the independent resources model can be addressed by the present data. One is the assumption that the hemispheres constitute independent resource pools, in that the resources of one hemisphere are not transferable to the other. The present study supports this assumption, because mutual decrements and trade-offs were not found when there was no overlap in resource demand. Therefore, left hemisphere resources were not being used to process the <u>attended</u> tone during left-ear target trials, nor could right hemisphere resources be used to improve performance on the load task.

A second assumption supported by the present data is that resources within a hemisphere can be allocated to tasks according to an allocation policy that is under the subject's control. In previous studies (e.g., see Friedman, Polson, Dafoe, and Gaskill, 1982), left hemisphere resources were shown to be allocatable. The results of the present study also demonstrate this, since, a shift in task emphasis resulted in differential performance trade-offs on the CVCVC and tone tasks when both required left hemisphere supplies.

A third assumption of the independent resources model is that resources within a hemisphere are undifferentiated. This means that regardless of the nature of tasks (e.g., auditory or visual), if they demand a particular hemisphere's resources, these can be used to perform any task that is processed in that hemisphere. This assumption is in direct conflict with Wickens' (1980; 1981) proposal that information processing resources are multi-dimensional. Wickens suggests that resources can be categorized by processing stages (perceptual/central processing vs. response processing), processing codes (verbal vs. spatial), and processing modalities (auditory vs. visual input, vocal vs. manual response). According to this view, the different modalities are likely to require processing resources from different pools. The present experiment clearly indicates that the visual and auditory tasks used required the same resources during right-ear tone task trials. Therefore, although further investigation is needed, it appears that modality-specific resource pools may not exist.

Aside from their implications for models of divided attention, the present results are also germane to the literature concerned with hemispheric processing. The selective activation model (Kinsbourne, 1970; 1973; 1974) would have a difficult time explaining the results of the main experiment. The model predicts that the verbal CVCVC memory task should have selectively activated the left hemisphere, so that performance on the right ear tone task trials should have been improved over baseline performance;

this is the opposite of what actually occurred. In addition, the selective activation theory cannot explain why a shift in task emphasis resulted in performance trade-offs during right ear trials, as attentional shifts are believed to merely alter the activation within the left hemisphere. Thus, an increment in performance on one task should be accompanied by an <u>increment</u> on the other task, rather than the decrements that were observed.

The functional cerebral distance model differs from the selective activation model [illegible] the independent-resources model, in that tasks are [illegible]d to occupy certain functional cerebral spaces. These spaces theoretically represent processing structures consisting of linked neural networks that are not differentially affected (in terms of what is linked to what) by attentional changes. Since many studies (e.g., Gordon, 1980; Kimura, 1964; Bever and Chiarillo, 1974) have shown that subjects tend to have a left ear advantage for remembering tones, the functional cerebral space associated with a music task must be assumed to be localized in the right hemisphere (Kinsbourne and Hicks, 1978). Furthermore, this would be the case regardless of whether the left or right ear receives the tone. During dichotic or binaural presentation, the tone presented to the right ear is thought to cross the corpus callosum to occupy the same functional cerebral space as the tone presented to the left ear. This is a crucial assumption of the model, and it highlights its structural nature and the concept that cognitive tasks are generally processed via structures that are localized in one or the other hemisphere.

The above assumptions lead to predictions of single-to-dual-task decrements and trade-offs on the CVCVC and tone tasks that are equivalent for both left-ear and right-ear trials. These predictions were not confirmed by the results of the main experiment. To account for this, the functional cerebral distance model would need to assume that the left and right ear tones are not processed by the same neural structure. Furthermore, since differential decrements occurred with shifts in task emphasis during right-ear trials but not during left-ear trials, the model must explain why shifts in selective attention from one ear to the other must have changed the neural structure(s) used to process the tones. To achieve this, the model would need to allow for independent changes of networks in functional cerebral space as a function of attentional shifts. This would be similar to the independent-resources assumption that attentional resources are differentially allocatable to different tasks. Such changes would undermine the structural assumptions of the functional cerebral distance model and make it difficult to distinguish it from the independent-resources model.

In summary, the data from the main experiment are in accord with the predictions of the independent-resources model. The major underlying assumptions of the model that are addressed by this study have been supported, whereas the predictions of the single-capacity model (Kahneman, 1973), the multi-dimensional model (Wickens, 1980; 1981), the selective activation model (Kinsbourne, 1970; 1973; 1974), and the functional cerebral distance model (Kinsbourne & Hicks, 1978; Kinsbourne, 1982) have all been found wanting to a greater or lesser extent.

The experimental control session was included to determine the extent to which the tone presented to the unattended ear is processed. It was expected that the unattended tone would either be totally ignored, and thus not affect judgment of the attended tone, or, that the unattended tone would be processed enough so that it might interfere with judgment of the attended tone. Surprisingly, both of these possibilities were found to occur. When the left ear was attended to, the tone presented to the right ear did not influence performance; however, when the right ear was attended to, performance on mixed trials (i.e., when the unattended dichotic tone matched the binaural tone) was poorer than on pure trials (i.e., when the unattended dichotic tone and the binaural tone were different). This result was quite unexpected and suggests that during right-ear attended trials, the tone presented to the left ear was processed to a certain degree, because it was confused with the attended tone, whereas on left-ear attended trials, the tone presented to the right ear was not processed to the same extent, insofar as it did not become confused with the attended tone. Although this result was not anticipated, it supports the idea that both hemispheres can do the processing required for many tasks, even though they may not be equally competent (Friedman & Polson, 1981). Importantly, these results contradict the functional cerebral distance model's assumption that the left and right ear tones are processed in the same functional cerebral space, and that this space is the same regardless of which ear is selectively attended to.

There is no *a priori* reason to believe that processing the right-ear tone can be voluntarily halted sooner than processing the left-ear tone. Therefore, a different explanation is needed for the obtained differences in interference from the unattended tone. One possibility is that the mere presence of a tone demands *R* resources when presented to either the attended or the unattended ear, that is, that a certain degree of mandatory processing is required. If so, then this could result in differentially processed inputs, depending on the slope of the performance resource function for each ear. Assuming that the right hemisphere was generally more efficient than the left for this task, the left-ear tone presumably would be processed to a greater extent than the right-ear tone, given *R* resources. Mandatory processing would be unique insofar as it would occur beyond the control of an allocation policy (see Navon and Gopher, 1979). It differs from automatic processing (Schneider and Shriffin, 1977), in that, whereas automatic processing may occur without requiring resources, mandatory processing implies that resources are needed.

It is possible to interpret the findings of the experimental control session in terms of mandatory processing of the tone in the unattended ear. On left-ear attended trials, the unattended tone presented to the right ear demanded a certain amount of mandatory resources from the left hemisphere. Because of the relatively inefficient processing of the right-ear tone by the left hemisphere, these mandatory resources were not enough to allow processing to reach the point where the tone was well enough articulated to compete with the attended tone. However, on right-ear attended trials, the left-ear (unattended) tone is processed more efficiently by the right hemisphere, and thus, the result of mandatory processing is a relatively well-articulated tone which is confused with the right-ear tone and which results in the observed increase in false alarms.

These notions may be used to explain some anomalous findings in the data from the main experiment. We assume that in a given hemisphere, the same performance-resource function for processing tones exists regardless of whether they are attended to, but that the utilization of resources differs as a function of selective attention. That is, resources in the relevant hemisphere would be voluntarily allocated to the tone during attended trials, so that the attended tone is further articulated. However, no more than the mandatory amount of resources would be allocated to the tone in the unattended ear. For example, during trials when the load task was emphasized, the right and left-ear tones would receive only the mandatory amount of resources they demanded, regardless of which ear was attended to. However, during target task emphasis, the amount of resources that a tone received would depend on whether or not that tone was being selectively attended to. During left-ear attended trials, the right hemisphere would allocate more resources to process the left-ear tone, whereas the right-ear tone would still receive only the mandatory amount of resources from the left hemisphere. During right-ear attended trials, the left-ear tone would only receive the mandatory amount of resources from the right hemisphere, but now the right-ear tone would be allocated more resources by the left hemisphere. Thus, a shift in task emphasis only affects the amount of resources allocated to the attended tone, increasing these beyond the mandatory resources demanded by the mere presence of the tone.

The occurrence of mandatory processing may explain why there were decrements on the memory load task during left-ear target trials. The mandatory amount of resources demanded by the right-ear (unattended) tone during these trials would take away from the total amount of left hemisphere resources available for processing the load task. Thus, performance on the load task would decrement from single task baselines. Since mandatory resources are independent of allocation policy, a shift in task emphasis should not vary the amount of resources demanded by the presence of the right-ear (unattended) tone, and consequently, load task decrements should not be differentiated across emphasis conditions. This explanation is consistent with the results.

Whether or not mandatory processing is an operationally useful and valid concept is an empirical question. With respect to the present experimental paradigm, it is necessary to determine if mandatory resources are demanded by the tone presented to the left ear. This could be achieved by combining the target task with a load task that requires right hemisphere resources. If the unattended left-ear tone undergoes mandatory processing, then performance decrements should be observed on a right hemisphere load task without accompanying trade-offs when the right ear tone is being attended to.

The usefulness of the mandatory processing concept is not restricted to the present experimental results, and it may allow further insight into other situations that involve attentional processing. For example, one reason bottleneck theories of divided attention were abandoned is that in some situations, various attributes of an unattended input were found to be available to the subject for futher processing. Early dichotic listening studies in which subjects were required to shadow a message have shown that while subjects may not be aware of the content of the message presented to the non-shadowed ear, changes in the physical characteristics are often noticed (Cherry, 1953). These results suggest that processing the non-shadowed input had reached the point at which physical characteristics of the message were articulated, but meaning and other "higher order" properties were not.

If we assume that the unattended message demands resources from the contralateral hemisphere, then the case in which only physical changes were noticed may reflect the fact that the mandatory resources were not sufficient to allow processing to continue to the extent that semantic properties were articulated. This explanation is based on the assumption that a continuum exists in which higher order attributes require more resources to be articulated than do lower order attributes. Other studies, however, have shown that in some situations, the meaning of unattended information is processed to some extent (e.g., Eich, 1982; Moray, 1959; Lewis, 1970; Straube and Germeer, 1979; Treisman, Squire, and Green, 1974). In these situations, processing of the unattended message must have been extended to the point that semantic articulation was reached.

There are several possible reasons why semantic articulation occurs in some instances but not in others. One possibility is that the amount of processing necessary for articulation of different attributes of an input may actually change, and may do so independently for each type of attribute. Thus, semantic properties of the unattended message may be available in some situations because the semantic articulation necessary for performance had been lowered. This explanation is similar to Norman's (1968) proposition that what is selectively attended to is greatly determined by currently activated memory representations. For example, a person's name seems to "jump out" when he or she is scanning a page of text, and the meaning of an unattended message may suddenly be noticed, because the input interacts with memorial representations and attention is directed towards pertinent information. To re-interpret Norman's ideas, pertinence may reflect lower levels of articulation required for certain information. Of course, in a complete account, it would be necessary to define what is and what is not pertinent for any given situation. However, these ideas are not incongruent with existing models of information processing which suggest that processing is guided from memorial representations that have been activated (Neisser, 1976; Posner, 1978). Furthermore, this approach may be relevant to the priming literature, where it has been shown that the nature of an unattended stimulus can influence the processing of several types of features of a corresponding target stimulus (e.g., Cortine and Dunn, 1974; Cortine & Wood, 1972; von Wright, Anderson, and Stenman, 1975).

A second possibility that would explain the occurrence of different degrees of mandatory processing is that the performance-resource functions associated with different situations may differ, where a steeper performance resource slope would result in more processing for a given amount of mandatory resources. Once again, it must be assumed that there exists a continuum of articulation ranging from lower to higher order attributes, and thus *R* mandatory resources would have a better chance of achieving higher order thresholds when applied to a more efficient process. This possibility is intriguing, but it requires investigation of some basic assumptions. First, it would be necessary to determine if the performance-resource function associated with any given input fluctuates or remains static. In support of the former, some researchers (e.g., see Navon and Gopher, 1979) have suggested that practice serves to increase performance on a task, given the same amount of resources, thus indicating that the process becomes more efficient.

The above examples of how different attributes of any given input may be articulated are merely skeletal frameworks, that take the "extent of processing" concept used by theorists in the attentional literature one step further. The task that remains is to investigate these empirically and to test the assumptions that accompany each hypothesis. Futhermore, these issues are not isolated from other issues in the psychological literature. For example, one area of research which may benefit is that concerned with levels of processing (Craik and Lockhart, 1972). Extrapolating from the framework presented earlier, it would be interesting to determine whether the various orienting tasks used in the levels paradigm serve to (a) change the articulation levels necessary for the different attributes associated with an event to be processed, (b) change the processes associated with the encoding of the stimuli, or (c) separate the input into different processes (e.g, physical vs. semantic levels) which then receive either more or less resources depending on the nature of the encoding task.

The occurrence of mandatory processing in the present study was an unexpected development. However, many studies have shown that unattended stimuli receive processing which result in a range of responses, from the "orienting response" (Pavlov, 1927) to evoked cortical potentials (Shucard, Shucard, & Thomas, 1977). The results of the present study similarily indicate that in some instances processing is mandatory. Therefore, although attention can be allocated, the assumption that all resources are allocatable (or not) cannot be made. In the future, theories of attentional processing must incorporate mandatory processing into their frameworks.

In conclusion, the results of the present study best support the independent-resources model. As predicted by the model, mutual tradeoffs between tasks were found to occur only on trials where complete overlap in resource demand was presumed to exist. Furthermore, the model's main underlying assumptions of resource supply independence, resource allocation, and undifferentiation of resources, were all supported by the data. In contrast, the predictions of the single capacity model (Kahneman, 1973), the multi-dimensional model (Wickens, 1980; 1981), the selective activation model (Kinsbourne, 1970; 1973; 1974), and the functional cerebral distance model (Kinsbourne and Hicks, 1978; Kinsbourne, 1982) were not supported. Therefore, future investigation of attentional processing should take into account the notion that the two cerebral hemispheres behave as independent resource pools.

The data from the experimental control session indicate that during right-ear trials, the tone presented to the left ear was confused with the attended tone, whereas, during left-ear attended trials, the tone presented to the right ear was not confused with the attended tone. To explain the differential interference effects of the unattended tone, and to account for some anomalous findings in the main experiment, it is suggested that the mere presence of a tone may demand resources.

It is important to note that the independent-resource model assumption that resources are allocatable according to some allocation policy is not being questioned, as allocation of resources is assumed to occur above and beyond mandatory processing. However, the possibility that resources may be demanded by the mere presence of stimuli should be given consideration in divided attention research.

References

Bever, T. & Chiarello, R. Cerebral dominance in musicians and nonmusicians. *Science*, 1974, *185*, 537-539.

Briggs, G.G. A comparison of attentional and shift models of the performance of concurrent tasks. *Acta Psychologica*, 1975, *35*, 183-191.

Broadbent, D.E. *Perception and Communication.* London:Pergamon Press Ltd., 1958.

Cherry, E.C. Some experiments on the recognition of speech, with one and with two ears. *Journal of the Acoustical Society of America*, 1953, *25*, 975-979.

Bever, T. & Chiarello, R. Cerebral dominance in musicians and nonmusicians. *Science*, 1974, *185*, 537-539.

Briggs, G.G. A comparison of attentional and shift models of the performance of concurrent tasks. *Acta Psychologica*, 1975, *35*, 183-191.

Broadbent, D.E. *Perception and Communication.* London:Pergamon Press Ltd., 1958.

Carpenter, M.B. *Human Neuroanatomy.,7th edition*, Williams and Wilkins Co., Baltimore, 1976.

Cherry, E.C. Some experiments on the recognition of speech, with one and with two ears. *Journal of the Acoustical Society of America*, 1953, *25*, 975-979.

Corteen, R.S. and Dunn, D. Shock-associated words in a nonattended message: A test for momentary awareness. *Journal of Experimental Psychology*, 1974, *102*, 1143-1144.

Corteen, R.S., and Wood, B. Autonomic responses to shock-associated words in an unattended channel. *Journal of Experimental Psychology*, 1972, *94*, 308-313.

Craik, F., and Lockhart, R.S. Levels of processing: A framework for memory research. *Journal of Verbal Learning and Behavior*, 1972, *11*, 671-684.

Deutsch, J.A., & Deutsch, D. Attention: Some theoretical considerations. *Psychological Review*, 1963, *70*, 80-90.

Dirks, D. Perception of dichotic and monaural verbal material and cerebral dominance in speech. *Acta Otolaryngologica*, 1964, 73-80.

Friedman A.R. & Polson M.C. The hemispheres as independent resource - systems: Limited capacity processing and cerebral specialization. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, *7*, 1031-1058.

Friedman A.R., Polson, M.C., Dafoe, C.G., & Gaskill, S. Dividing attention within and between hemispheres: Testing a multiple resources approach to limited-capacity information processing. *Journal of Experimental Psychology: Human Perception and Performance*, 1982, in press.

Gazzaniga M.S. *The Bisected Brain*. New York: Appleton Century - Crofts, 1970.

Gazzaniga M.S. One brain - two minds. *American Scientist*, 1972, *60*, 311-317.

Geffen, G., Bradshaw, J.L., & Nettleton, N.C. Hemispheric asymmetry: verbal and spatial encoding of visual stimuli. *Journal of Experimental Psychology*, 1972, *95*,

25-3

Geffen, G., Bradshaw, J.L., & Wallace, G. Interhemispheric effects on reaction time to verbal and nonverbal visual stimuli. *Journal of Experimental Psychology*, 1971, *87*, 415-422.

Gordon, H.W. Degree of ear asymmetry for perception of dichotic chords and for illusory chord localization in musicians of different levels of competence. *Journal of Experimental Psychology*, 1980, *6*, No.3, 516-527.

Hardyck, C., and Petrinovich, L.F. Left-handedness. *Psychological Bulletin*, 1977, *84*, 385-404.

Hellige, J.B. & Cox, P.J. Effects of concurrent verbal memory on recognition of stimuli from the left and right visual fields. *Journal of Experimental Psychology*, 1976, *2*, 210-221.

Hellige, J.B., Cox, P.J. & Litvak, L. Information processing in the cerebral hemispheres: Selective hemispheric activation and capacity limitations. *Journal of Experimental Psychology: General*, 1979, *108*, 251-279.

Hicks, R. E. Intrahemispheric response competition between vocal and unimanual performance in normal adult human males. *Journal of Comparative and Physiological Psychology*, 1975, *89*, 50-60.

Hicks, R.E., Bradshaw, G.J., Kinsbourne, M., and Feigin, D.S. Vocal-manual trade-offs in hemispheric sharing of human performance control. *Journal of Motor Behavior*, 1978, *10*, 1-6.

Hicks, R.E., Porvenzano, F.J., and Rybstein, E.D. Generalized and lateralized effects of concurrent verbal rehearsal upon performance of sequential movements of the fingers by the left and right hands. *Acta Psychologica*, 1975, *39*, 119-130.

Jerger, J.K. and Mier, M. The effects of brain stem lesion on auditory responses of humans. Paper presented at the First Annual Meeting of Psychonomic Society, Chicago, Sept., 1960. As cited in Mountcastle, V.B. *Interhemispheric Relations and Cerebral Dominance.* John Hopkins Press, Baltimore, 1962.

Kahneman, D. *Attention and Effort.* Englewood Cliffs, N.J., Prentice Hall, 1973.

Kimura, D. Left-right differences in the perception of melodies. *Quarterly Journal of Experimental Psychology*, 1964, *16*, 335-358.

Kimura, D. Functional asymmetry of the brain in dichotic listening. *Cortex*, 1967, *3*, 163-178.

Kinsbourne, M. The central basis of lateral asymmetries in attention. *Acta Psychologia*, 1970, *33*, 193-201.

Kinsbourne, M. The control of attention by interaction between the cerebral hemispheres. In S. Kornblum (Ed.), *Attention and Performance IV*. New York: Academic Press, 1973.

Kinsbourne, M. Lateral interactions in the brain. In M. Kinsbourne and W.L. Smith (Eds.), *Hemispheric Disconnection and Cerebral Function.* Springfield, Ill.: Charles C.Thomas, 1974.

Kinsbourne, M. The mechanism of hemispheric control of the lateral gradient of attention. In P.M.A. Rabbitt & S. Dornic (Eds.), *Attention and Performance V*. New York: Academic Press, 1975.

Kinsbourne, M. Hemispheric specialization and the growth of human understanding. *American Psychologist*, 1982, *37*, 411-420.

Kinsbourne, M. & Cook, J. Generalized and lateralized effects of concurrent verbalization on a unimanual skill. *Quarterly Journal of Experimental Psychology*, 1971, *23*, 341-345.

Kinsbourne, M. & Hicks, R.E. Functional cerebral space: A model for overflow, transfer, and interference effects in human performance. In J. Requin (Ed.), *Attention and Performance VII*. New Jersey: Lawrence Erlbaum, 1978.

Kinsbourne, M. & Hiscock, M. Asymmetries of dual-task performance. In Hellige, J.B. (Ed.), *Cerebral Hemisphere Asymmetry: Method, Theory, and Application*. New York: Praeger Press, 1983.

Levy, J., Trevarthen, C., & Sperry, R.W. Perception of bilateral chinuvic figures following hemispheric deconnection. *Brain*, 1972, *95*, 61-78.

Luria, A.R. *Traumatic Aphasia*. The Hague: Mouton. 1970.

Lewis, J.L. Semantic processing of unattended messages using dichotic listening. *Journal of Experimental Psychology*, 1972, *94*, 308-313.

Lindsay, P.H. Multichannel processing in perception. In

D.F. Mostafsky (Ed.), *Contemporary Theory and Analysis*, New York: Appleton-Century-Crofts, 1970.

Lindsay, P.H., Taylor, M.M., & Forbes, S.M. Attention and multichannel discrimination. *Perception and Psychophsics*, 1968, *4*, 113-117.

Meyers, R.E. & Sperry, R.W. Interocular transfer of a visual form discrimination habit in cats after section of the optic chiasm and corpus callosum. *Anatomical Records*, 1953, *115*, 351-352.

Milner, B. Taylor, L., & Sperry, R.W. Lateralized suppression of dichotically presented digits after commissural section in man. *Science*, 1968, *161*, 184-186.

Moray, N. Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology*, 1959, *11*, 59-60.

Moray, N. Time sharing in auditory perception: Effect of stimulus duration. *Journal of the Acoustical Society of America*, 1970a, *47*, 660-661.

Moray, N. Introductory experiments in auditory time sharing: Detection of intensity and frequency increments. *Journal of the Acoustical Society of America*, 1970b, *47*, 1071-1073.

Moray, N. & O'Brien, T. Signal detection theory applied to selective listening. *Journal of the Acoustical Society of America*, 1967, *42*, 765-772.

Moscovich M. & Klein, D. Material-specific perceptual interference for visual words and faces: Implications for models of capacity limitations, attention and laterality. *Journal of Experimental Psychology: Human Performance and Perception*, 1980, *6*, 590-604.

Navon, D. & Gopher, D. On the economy of the human information-processing system. *Psychological Review*, 1979, *86*, 214-255.

Navon, D., & Gopher D. Task difficulty, resources, and dual-task performance. In R. S. Nickerson (Ed.), *Attention and Performance VIII*, Hillsdale, N.J.: Erlbaum, 1980.

Neisser, E. *Cognitive Psychology*. New York: Appleton-Century-Crofts, 1967.

Neisser, E. *Cognition and Reality*. San Francisco: Freeman, 1976.

Ninio, A. & Kahneman, D. Reaction time in focused and in divided attention. *Journal of Experimental Psychology*, 1973.

Norman, D.A. Toward a theory of memory and attention. *Psychological Review*, 1968, *75*, 522-536.

Norman, D.A. & Bobrow, D.G. On data-limited and resource limited processes. *Cognitive Psychology*, 1975, *7*, 44-64.

Norman, D.A. *Memory and Attention: An Introduction to Human Information Processing*. John Wiley & Sons, Inc., 1969.

Pavlov, I.A. *Conditioned Reflexes*. (Translated by G.V. Anrep.) London: Oxford, 1927 (Reprinted, New York:Dover, 1960.).

Raczkowski, D., Kalat, J.W., & Nebes, R. Reliability and validity of some handedness questionnaire items. *Neuropsychologia*, 1974, *12*, 43-47.

Rosenzweig, M.R. Representation of the two ears at the auditory cortex. *American Journal of Physiology*, 1951, *167*, 147-158.

Rosenzweig, M.R. Cortical correlates of auditory localization and of related perceptual phenomena. *Journal of Comparitive and Physiological Psychology*, 1954, *47*, 2[illegible]76.

Rosenzweig, M.R. Auditory localization. *Scientific American*, 1961, *205*, 132-142.

Schneider, W., & Shriffin, R.M. Controlled and automatic human information processing: I: Detection, search and attention. *Psychological Review*, 19[illegible], *34*, No. 1, 1-66.

Shucard, D.W., Shucard, J.L., & Thomas D.G. Audutory evoked potentials as probes of hemispheric differences in cognitive processing. *Science*, 1977, *197*, 1295-1298.

Sinha, S.P. The role of the temporal lobe in hearing. Unpublished Master's thesis, McGill University, 1959. As cited in Mountcastle, V.B. *Interhemispheric Relations and Cerebral Dominance*. John Hopkins Press, Baltimore, 1962.

Smith, M.A., Chu, J., & Edmonston, W.E. Cerebral lateralization of haptic perception: Interaction of responses to Braille and music reveals a functional basis. *Science*, 1977, *197*, 689-690.

Sparks, R. and Geschwind, N. Dichotic listening in man after section of neocortical commisssures. *Cortex*, 1968, *4*, 3-16.

Sparks, R., Goodglass, H., and Nickel, B. Ipsilateral versus contralateral extinction in dichotic listening resulting from hemispheric lesions. *Cortex*, 1970, *6*, 249-260.

Sperry, R. W. Cerebral organization and behavior. *Science*, 1961, *133*, 1749-1757.

Sperry R. W. Hemispheric deconnection and unity in conscious awareness. *American Psychologist*, 1968, *23*, 723-733.

Straube, E.R., & Germerr, C.K. Dichotic shadowing and selective attention to word meanings in schizophrenics. *Journal of Abnormal Psychology*, 1979, *88*, 346-353.

Treisman, A.M. Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology*, 1960, *12*, 242-248.

Treisman, A.M. Perception and recall of simultaneous speech stimuli. *Acta Psychologia*, 1970, *33*, 132-148.

Treisman, A.M., & Fearnley, J.S. Can simultaneous speech stimuli be classified in parallel? *Perception and Psychophysics*, 1971, *10*, 1-7.

Treisman, A.M., Squire, R., & Green, J. Semantic processing in dichotic listening: A replication. *Memory and Cognition*, 1974, *2*, 641-646.

Tunturi, A.R. A study on the pathway from the medial geniculate body to the acoustic cortex in the dog. *American Journal of Physiology*, 1946, *147*, 311-319.

Underwood, G. Moray vs. the rest: The effects of extended practice on shadowing. *Quarterly Journal of Experimental Psychology*, 1974, *26*, 368-373.

Von Wright, J.M., Anderson, K., & Stenman, U. Generalization of conditioned dichotic listening. In P.M.A. Rabbitt & S. Dornic (Eds.), *Attention and Performance V*. London: Academic Press, 1975.

White, M.J. Visual hemifield differences in the perception of letters and contour orientation. *Canadian Journal of Psychology*, 1971, *26*, 207-212.

Wickens, C.D. The structure of attentional resources. In R. S. Nickerson (Ed.), *Attention and Performance VIII*, Hillsdale, N.J.: Erlbaum, 1980.

Wickens, C.D. Multiple resources in time-sharing. In Lansman, M. & Hunt, E. (Eds.), *Proceedings of the Lake Wilderness Attention Conference Technical Paper No. 10*, 1981.

Zelnicker, T. Perceptual attenuation of an irrelevant auditory verbal input as measured by an involuntary verbal response in a selective attention task. *Journal of Experimental Psychology*, 1971, *87*, 52-56.

APPENDIX A

Stimulus Materials

Table 1

Experimental Day: Tone Stimulus Sets

Yes Trials

	Attended	Unattended	Binaural
1.	330	311	330
2.	370	349	370
3.	415	392	415
4.	466	440	466
5.	523	494	523
6.	587	554	587
7.	311	330	311
8.	349	370	349
9.	392	415	392
10.	440	466	440
11.	494	523	494
12.	554	587	554

No Trials

	Attended	Unattended	Binaural
1.	311	330	349
2.	370	349	392
3.	392	415	440
4.	466	440	494
5.	494	523	554
6.	587	554	622
7.	330	311	294
8.	349	370	330
9.	415	392	370
10.	440	466	415
11.	523	494	466
12.	554	587	523

Table 2

Control Day: Tone Stimulus Sets-Block One

Yes Trials

	Attended	Unattended	Binaural
1.	330	311	330
2.	370	349	370
3.	415	392	415
4.	466	440	466
5.	523	494	523
6.	587	554	587
7.	311	330	311
8.	349	370	349
9.	392	415	392
10.	440	466	440
11.	494	523	494
12.	554	587	554

No Trials: Match(M) and Non-Match(N)

	Attended	Unattended	Binaural
1.	311	330	(M) 330
2.	370	349	(N) 392
3.	392	415	(M) 415
4.	466	440	(N) 494
5.	494	523	(M) 523
6.	587	554	(N) 622
7.	330	311	(M) 311
8.	349	370	(N) 330
9.	415	392	(M) 392
10.	440	466	(N) 415
11.	523	494	(M) 494
12.	554	587	(N) 523

Table 3

Control Day: Tone Stimulus Sets-Block Two

Yes Trials

	Attended	Unattended	Binaural
1.	330	311	330
2.	370	349	370
3.	415	392	415
4.	466	440	466
5.	523	494	523
6.	587	554	587
7.	311	330	311
8.	349	370	349
9.	392	415	392
10.	440	466	440
11.	494	523	494
12.	554	587	554

No Trials:Match(M) and Non-Match(N)

	Attended	Unattended	Binaural
1.	311	330	(N) 330
2.	370	349	(M) 349
3.	392	415	(N) 415
4.	466	440	(M) 440
5.	494	523	(N) 523
6.	587	554	(M) 554
7.	330	311	(N) 311
8.	349	370	(M) 370
9.	415	392	(N) 392
10.	440	466	(M) 466
11.	523	494	(N) 494
12.	554	587	(M) 587

APPENDIX B

Tables of Mean Values

Table 4

Mean Percent Single-Task, Dual-Task, and Single-Task to Dual-Task Decrements During Left Ear Attended (LEA) and Right Ear Attended (REA) Trials: CVCVC Memory Task.

(a) CVCVC Memory Emphasis

Subject	Single	Dual LEA	Dual REA	Decrements LEA	Decrements REA
01	45.0	38.3	30.0	06.7	15.0
02	73.3	66.1	61.7	06.6	11.6
03	78.3	78.3	66.6	00.0	11.6
04	81.7	38.3	63.3	43.4	18.4
05	63.3	45.0	61.7	18.3	01.6
06	28.3	23.3	40.0	05.0	-11.7
07	20.0	11.7	15.0	08.3	05.0
08	38.3	20.0	30.0	18.3	08.3
Mean	53.5	40.2	46.1	13.3	07.5
S.D.	23.8	23.0	19.8	13.7	09.4

(b) Tone Memory Emphasis

Subject	Single	Dual LEA	Dual REA	Decrements LEA	Decrements REA
01	45.0	45.0	20.0	00.0	25.0
02	75.0	46.7	41.7	28.3	33.3
03	80.0	65.0	61.7	15.0	18.3
04	71.7	70.0	58.3	01.7	13.4
05	68.3	48.3	53.3	20.0	15.0
06	43.3	26.7	15.0	16.6	28.3
07	15.0	16.7	16.7	-01.7	-01.7
08	38.3	31.7	20.0	06.6	18.3
Mean	54.6	43.8	35.8	10.8	18.7
S.D.	22.7	18.3	20.1	10.8	10.7

Table 5

Mean Percent Single-Task, Dual-Task, and Single-Task to Dual-Task Decrements During Left ear Attended (LEA) and Right Ear Attended (REA) Trials: Tone Memory Task.

(a)CVCVC Memory Emphasis

	Single		Dual		Decrements	
Subject	LEA	REA	LEA	REA	LEA	REA
01	90.0	85.0	75.0	70.0	15.0	15.0
02	100.0	95.0	95.0	90.0	05.0	05.0
03	90.0	100.0	80.0	80.0	10.0	20.0
04	75.0	65.0	75.0	55.0	00.0	10.0
05	55.0	65.0	55.0	55.0	00.0	10.0
06	85.0	85.0	75.0	75.0	10.0	10.0
07	50.0	55.0	60.0	55.0	-10.0	00.0
08	60.0	55.0	70.0	65.0	-10.0	-10.0
Mean	75.6	75.6	73.1	68.1	02.5	07.5
S.D.	18.6	17.8	12.2	13.1	09.3	09.3

(b)Tone Memory Emphasis

	Single		Dual		Decrements	
Subject	LEA	REA	LEA	REA	LEA	REA
01	80.0	65.0	55.0	80.0	25.0	[illegible]5.0
02	95.0	80.0	95.0	95.0	00.0	-15.0
03	90.0	65.0	100.0	95.0	-10.0	-30.0
04	55.0	55.0	60.0	75.0	-05.0	-20.0
05	55.0	65.0	80.0	60.0	-25.0	05.0
06	75.0	75.0	65.0	40.0	10.0	35.0
07	60.0	65.0	60.0	60.0	00.0	05.0
08	65.0	85.0	60.0	75.0	05.0	10.0
Mean	71.9	69.4	71.9	72.5	00.0	-03.1
S.D.	15.6	09.8	17.5	18.7	14.6	20.9

APPENDIX C

Instructions

Instructions

CVCVC Naming Task Screening

Today you will be first performing a screening session. Depending on your results, you may or may not be asked to participate futher in the experiment. Your performance on the screening session is not related to anything such as I.Q. or personality, and the basis of whether or not you are asked to participate further in this experiment does not concern itself from your absolute score. Therefore, we only ask that you follow the instructions and try to do your best.

The first task will involve naming five-letter nonsense words that will appear to the left or right of center on the screen in front of you. Half of the words will appear on the left and half on the right, and each side they appear on will be random. Consequently, your best strategy will be to stare at a fixation dot that comes on the center of the screen before each trial. All of the words will be printed vertically (show example), and as I said, they will be nonsense words. Now, since you've likely never seen these words before, you may have problems pronouncing them. It is for this reason that I'm going to give you a list of the words you will be seeing and have you read them aloud so you can get used to them. (Give subject list and have him read it aloud).

You will be sitting with your head resting in this chinrest. For each trial, you'll hear a beep and about a half second later a fixation dot will come on the center of the screen. It's important that you focus on the dot because about two seconds later a word will be flashed on very briefly and you will have to name it aloud. Since the words come on so briefly, you should not expect to see all of them so it's OK to guess if you want to.

We will start with ten practice trials. So it's a beep, followed a half second later by a fixation dot that you focus on for two seconds, and then the word comes on and you are to say it aloud. Any questions?

Tone Memory Screening and Single-Task Trials

In this part of the experiment you will be hearing sounds presented to you through these headphones. You will be required to judge some of these sounds in terms of pitch.

For each trial you will first hear a warning "click". This click indicates that a trial has started. Half a second after the click, a square box will appear on the screen. You are to just look at this until is disappears two and a half seconds later. Shortly after the square goes off you will hear two different tones. One tone will be presented to your left ear, and the other to your right ear. You will be asked to listen to only one ear, while ignoring the other ear completely, by directing all of your attention to one ear. After these tones are presented there is a three second pause and then you will hear another tone. This tone is presented to both ears but once again you will be asked to listen with only one ear. Your job is to decide whether or not the first tone that was presented to the ear you are paying attention to, matches the pitch of the second tone presented to the ear.

For example, if you are asked to listen to your right ear, and the first tone (following the warning "click") was this (give example) and then three seconds later the second tone presented to that ear was this (example tone - same pitch), you should indicate that the tone matched. However, if the first tone was this (give example) but the second tone was this (example tone - different pitch) then you should indicate that the tones are different. To indicate your decision you are to use these response plates. (Explain the response plates).

Throughout the experiment it is very important that you listen with only the ear that you are instructed to listen with. The sounds presented to your "other" ear may act as distracters. Therefore, if you accidently listen to the wrong ear, you may be more likely to make an incorrect decision. So once again, it is very important that you listen to the attended-to-ear only. All judgements that you make should be based on the tones that you hear in that ear.

You will be paid for your performance on this task. Each time you have made a correct decision (e.g., responding 'yes' when the tones matched or 'no' when the tones did not match), you will earn five cents. If you respond incorrectly, you will not be rewarded.

At this point, we will do a few practice trials to familiarize you with the task. Before each trial (practice) I will tell you what the correct answer should be. If you have any questions about the task, please feel free to ask me now or during the practice.

CVCVC Memory Single-Task Trials

This task is a word memory task. It involves remembering three five-letter nonsense words over a period of time. Each trial goes as follows: you'll hear a beep and then a fixation dot will appear on the screen. You'll focus on the dot and about one half second later, three nonsense words will appear on the screen. They will be displayed horizontally, one underneath the other. When the words appear, you should say them aloud to me. The words will go off after two and a half seconds, there will be a five second pause, and then there will be another beep. When you hear the second beep, you should say as many of the words as you can back to me.

You will have the opportunity to make money on this task. Each time you correctly recall all three of the nonsense words you will earn five cents. If you do not recall all three, you will not earn any money. There will be some practice trials and then we will run the real trials. Are there any questions?

Dual Task Trials

The next task is a combination of the two you just did. You will be performing the nonsence word memory task and the tone matching task at the same time. Each trial works as follows: You'll hear a warning 'click' followed one half second by three nonsense words which you should say out loud to me. After these disappear, the tone matching task will begin, that is, you will hear two tones presented for two and a half seconds, a three second pause, and then a last tone. You will be matching the tones presented to one of your ears as you did earlier. As soon as you have made your response to the tone task, you are to say out loud the three nonsense words that you saw earlier and were keeping in memory.

CVCVC memory task emphasis. For the following set of trials you will earn more money for the nonsense word memory task than you will for the tone matching task. If you recall all three of the nonsense words you will earn four cents, and if you respond correctly to the tone task you will make one cent. Therefore, for each trial you can earn up to five cents. Thus, it is to your advantage to place more attention towards performing the nonsense word memory task than the tone matching task. We will run through a few practice trials and then do the real trials. (Instruct regarding which ear to attend to.)

Tone task emphasis. For the following set of trials you will earn more money for the tone matching task than you will for the nonsense word memory task. If you respond correctly to the tone task you will make four cents and if you recall all three nonsnese words you will make one cent. Therefore, you should pay more attention to the tone matching task than to the nonsense word memory task. We will run through a few practice trials and then do the real trials.

APPENDIX D

Computer Programs

```
        PROGRAM DAY1
C
C MAR 20/82 (ADAPTED FROM ONR3D1.FOR)
C
C THIS PROGRAM IS USED TO RUN THE SCREENING DAY (DAY1) OF
C HERD1 (1982).
C
C       1. PRESENTS A HANDEDNESS AND FAMILY HISTORY
C          QUESTIONNAIRE TO THE SUBJECT
C       2. PRESENTS AND SCORES 72 TINE MATCHING TRIA
C          LS (36/EAR)
C       3. PRESENTS TRIALS OF A VISUAL FIELD CVCVC N
C          AMING TASK
C          AND SCORES THEM
C
C
C SET CLOCK OSCILLATING IN MSEC
C
        CALL CLOCKB(4,-1,,IND)
C
C PAUSE THE TAPE RECORDER:
C
        CALL DOUT(0,"20000,IERR,"0)
C
C INTRODUCTION
C
        TYPE 5
        TYPE *,'           Welcome to HERD1 '
        TYPE 5
 5      FORMAT (/)
C
C GET DATE AND VERIFY
C
        CALL IDATE(NMON,NDAY,NYR)
        TYPE *,' Please verify: today''s date is: '
        TYPE *,'                  .',NMON,NDAY,NYR
        TYPE *,'                  1 = YES.'
        TYPE *,'                  0 = NO.'
        ACCEPT *,IRS
        IF(IRS.NE.1) GO TO 13
        GO TO 17
C
 13     TYPE 5
 15     TYPE *,'Enter today''s date: dd mon yr (ie 1
             3 06 80 ) '
        ACCEPT 14,NDAY,NMON,NYR
 14     FORMAT (I2,1X,I2,1X,I2)
        TYPE 16,NMON,NDAY,NYR
 16     FORMAT (28H Please verify today's date:,1X,I
               2,1X,I2,1X,I2)
```

```
      TYPE *,'                         1 = YES.'
      TYPE *,'                         0 = NO.'
      ACCEPT *,IRS
      IF(IRS.NE.1)GO TO 15
C
C GATHER A BUNCH OF INFORMATION
C
 17   TYPE 5
      TYPE *,' Enter subject number: '
      ACCEPT *,ISUBNO
      TYPE 5
      TYPE*,'  Please verify that subject number i
               s',ISUBNO
      TYPE*,'                           1=YES'
      TYPE*,'                           0=NO'
      ACCEPT*,IRS
      IF(IRS.NE.1)GO TO 17
C
      TYPE 5
 20   TYPE *,' How old is the subject?'
      ACCEPT *,IAGE
      TYPE 5
      TYPE*,'  Please verify that age is',IAGE
      TYPE*,'                           1=YES'
      TYPE*,'                           0=NO'
      ACCEPT*,IRS
      IF(IRS.NE.1) GO TO 20
C
      TYPE 5
 18   TYPE *,' With which HAND does the subject write?'
      TYPE *,'                         1 = RIGHT.'
      TYPE *,'                        -1 = LEFT.'
      ACCEPT *,IWRITE
      IF(IWRITE.NE.-1.AND.IWRITE.NE.1) GO TO 18
C
      TYPE 5
 19   TYPE *,'What is Subject''s WRITING POSTURE?'
      TYPE *,'                         1 = NORMAL.'
      TYPE *,'                        -1 = INVERTED.'
      ACCEPT *,IPOST
      IF(IPOST.NE.-1.AND.IPOST.NE.1) GO TO 19
C
C
      PAUSE 'ADVANCE PRINTER TO TOP OF PAGE AND HI
           T RETURN'
C
C WRITE THE DATA JUST COLLECTED TO THE LP
C
      WRITE(2,25)NMON,NDAY,NYR
 25   FORMAT(//,30X,'HERD1 - DAY 1 SCREENING',/,40X,
     1 'DATE:',I2,'-',I2,'-',I2)
```

```
        WRITE(2,26)ISUBNO,IAGE,IWRITE,IPOST
  26    FORMAT(//,1X,'SUBJECT ',I2,1X,'AGE ',I2,1X,'
            WRITING HAND ',I2,
     1  1X,'POSTURE ',I2)
C
        REWIND 2
C
C CALL THE SUBROUTINE WHICH DETERMINES CONDITION
C
        CALL TASK
C
C STOP CLOCK OSCILLATING
C
        CALL CLOCKB(0,,,IND)
C
        STOP
        END
                SUBROUTINE QUEST
C
        DIMENSION IBFRS(10),IRS(15)
        DATA NLRS,NRRS,NBRS,NNRS,NTRS/5*0/
C
        TYPE*,'  '
        TYPE*,'  '
        TYPE*,'  '
        TYPE*,'                          QUESTIONAIRE'
        TYPE*,'  '
        TYPE*,' This questionaire is designed to dis
               cover which hand'
        TYPE*,' you use in performing various manual
                    tasks.'
        TYPE*,'  '
        TYPE*,'  '
        TYPE*,'Type In answer to the following questions:    '
C
        TYPE*,' Enter a 1 if you perform the task be
               tter with your
     1RIGHT hand.'
        TYPE*,' Enter a 2 if you perform the task be
               tter with your
     1LEFT hand.'
        TYPE*,' Enter a 3 if you perform the task eq
           ually well with
     1BOTH hands.'
        TYPE*,' Enter a 4 if you have NO EXPERIENCE
           with the task.'
        TYPE*,''
        TYPE*,''
        TYPE*,' Assume that your hands are EMPTY (ex
           cept as indicated)'
```

```
          TYPE*,' before performing each task.'
          TYPE*,'  '
          TYPE*,' If you have any questions, please as
                   k the experimenter'
          TYPE*,' at this time.'
          TYPE*,''
C
          PAUSE ' To continue press RETURN  '
C
C CLEAR SCREEN
C
          CALL CLEAR
C
C
          TYPE*,''
          TYPE*,''
          TYPE*,'                      PART ONE      '
          TYPE*,''
          TYPE*,''
C
 1        TYPE 111
 111      FORMAT (' With which hand do you:     ',/)
C
          TYPE *,'      1.DRAW?  '
          CALL CHOICE
          ACCEPT *,IRS(1)
          IF(IRS(1).NE.1.AND.IRS(1).NE.2.AND.IRS(1).NE
            .3.AND.
     1          IRS(1).NE.4) GO TO 1
C
```

```
      CALL CLEAR
 2    TYPE 111
      TYPE *,'      2.WRITE?  '
      CALL CHOICE
      ACCEPT *,IRS(2)
      IF(IRS(2).NE.1.AND.IRS(2).NE.2.AND.IRS(2).NE
         .3.AND.
     1        IRS(2).NE.4) GO TO 2
C
      CALL CLEAR
 3    TYPE 111
      TYPE*,'      3. REMOVE THE TOP CARD FROM A D
            ECK OF CARDS (i.e.,
     1 DEALING) ?  '
      CALL CHOICE
      ACCEPT *,IRS(3)
      IF(IRS(3).NE.1.AND.IRS(3).NE.2.AND.IRS(3).NE
        .3.AND.
     1        IRS(3).NE.4) GO TO 3
C
      CALL CLEAR
 4    TYPE 111
      TYPE *,'      4. USE A BOTTLE OPENER?  '
      CALL CHOICE
      ACCEPT *,IRS(4)
      IF(IRS(4).NE.1.AND.IRS(4).NE.2.AND.IRS(4).NE
         .3.AND.
     1        IRS(4).NE.4) GO TO 4
C
      CALL CLEAR
 5    TYPE 111
      TYPE *,'      5. THROW A BASEBALL TO HIT A TARGET?'
      CALL CHOICE
      ACCEPT *,IRS(5)
        IF(IRS(5).NE.1.AND.IRS(5).NE.2.AND.IRS(5).
           NE.3.AND.
     1        IRS(5).NE.4) GO TO 5
C
      CALL CLEAR
 6    TYPE 111
      TYPE *,'      6. USE A HAMMER?  '
      CALL CHOICE
      ACCEPT *,IRS(6)
        IF(IRS(6).NE.1.AND.IRS(6).NE.2.AND.IRS(6).
           NE.3.AND.
     1        IRS(6).NE.4) GO TO 6
C
      CALL CLEAR
 7    TYPE 111
      TYPE *,'      7. USE A TOOTHBRUSH?  '
```

```
      CALL CHOICE
      ACCEPT *,IRS(7)
        IF(IRS(7).NE.1.AND.IRS(7).NE.2.AND.IRS(7).
           NE.3.AND.
     1        IRS(7).NE.4) GO TO 7
C
      CALL CLEAR
 8    TYPE 111
      TYPE *,'      8. USE A SCREWDRIVER? '
      CALL CHOICE
      ACCEPT *,IRS(8)
        IF(IRS(8).NE.1.AND.IRS(8).NE.2.AND.IRS(8).
           NE.3.AND.
     1        IRS(8).NE.4) GO TO 8
C
      CALL CLEAR
 9    TYPE 111
      TYPE *,'      9. USE AN ERASER ON PAPER?  '
      CALL CHOICE
      ACCEPT *,IRS(9)
        IF(IRS(9).NE.1.AND.IRS(9).NE.2.AND.IRS(9).
           NE.3.AND.
     1        IRS(9).NE.4) GO TO 9
C
      CALL CLEAR
 10   TYPE 111
      TYPE *,'     10. USE A TENNIS RACKET?  '
      CALL CHOICE
      ACCEPT *,IRS(10)
        IF(IRS(10).NE.1.AND.IRS(10).NE.2.AND.IRS(1
           0).NE.3.AND.
     1        IRS(10).NE.4) GO TO 10
C
      CALL CLEAR
 11   TYPE 111
      TYPE *,'     11. USE SCISSORS?  '
      CALL CHOICE
      ACCEPT *,IRS(11)
        IF(IRS(11).NE.1.AND.IRS(11).NE.2.AND.IRS(1
           1).NE.3.AND.
     1        IRS(11).NE.4) GO TO 11
C
      CALL CLEAR
 12   TYPE 111
      TYPE *,'     12. HOLD A MATCH WHEN STRIKING IT? '
      CALL CHOICE
      ACCEPT *,IRS(12)
        IF(IRS(12).NE.1.AND.IRS(12).NE.2.AND.IRS(1
           2).NE.3.AND.
     1        IRS(12).NE.4) GO TO 12
```

```
C
        CALL CLEAR
 13     TYPE 111
        TYPE *,'    13. STIR A LIQUID? '
        CALL CHOICE
        ACCEPT *,IRS(13)
          IF(IRS(13).NE.1.AND.IRS(13).NE.2.AND.IRS(1
             3).NE.3.AND.
     1          IRS(13).NE.4) GO TO 13
C
        CALL CLEAR
 14     TYPE*,'     14. ON WHICH SHOULDER DO YOU RES
            T A BAT BEFORE
     1SWINGING? '
        TYPE*,''
        TYPE*,'              1 = RIGHT SHOULDER'
        TYPE*,'              2 = LEFT SHOULDER'
        TYPE*,'              3 = EITHER SHOULDER EQUALLY WELL'
        TYPE*,'              4 = NO EXPERIENCE WITH TASK'
        ACCEPT *,IRS(14)
          IF(IRS(14).NE.1.AND.IRS(14).NE.2.AND.IRS(1
            4).NE.3.AND.
     1          IRS(14).NE.4) GO TO 14
C
        CALL CLEAR
 15     TYPE*,'     15. WITH WHICH FOOT DO YOU KICK
          A BALL? '
        TYPE*,'
        TYPE*,'              1 = RIGHT FOOT'
        TYPE*,'              2 = LEFT FOOT'
        TYPE*,'              3 = EITHER FOOT EQUALLY WELL'
        TYPE*,'              4 = NO EXPERIENCE WITH TASK'
        ACCEPT *,IRS(15)
          IF(IRS(15).NE.1.AND.IRS(15).NE.2.AND.IRS(1
            5).NE.3.AND.
     1          IRS(15).NE.4) GO TO 15
C
C
        CALL CLEAR
C
C
        TYPE*,''
        TYPE*,''
        TYPE*,''
        TYPE*,''
        TYPE*,'                      PART TWO
        TYPE*,''
        TYPE*,''
        TYPE*,' Which hand to the following people
                in your immediate'
```

```
      TYPE*,' BIOLOGICAL family use to write with?'
      TYPE*,''
19    TYPE *,'        1. YOUR FATHER ?'
      TYPE *,''
      TYPE *,'                    0=DONT KNOW--PLEASE
              TELL EXPERIMENTER'
      TYPE *,'                    1=RIGHT HAND'
      TYPE *,'                    2=LEFT HAND'
      ACCEPT *,IBFRS(1)
        IF(IBFRS(1).NE.0.AND.IBFRS(1).NE.1.AND.IBF
                   RS(1).NE.2)
     1          GO TO 19
C
      CALL CLEAR
      TYPE *,' '
20    TYPE *,'        2. YOUR MOTHER ? '
      TYPE *,''
      TYPE *,'                   0=DONT KNOW--PLEASE
              TELL EXPERIMENTER'
      TYPE *,'                    1=RIGHT HAND'
      TYPE *,'                    2=LEFT HAND'
      ACCEPT *,IBFRS(2)
        IF(IBFRS(2).NE.0.AND.IBFRS(2).NE.1.AND.IBF
           RS(2).NE.2)
     1          GO TO 20
C
      CALL CLEAR
      TYPE*,''
      TYPE*,''
67    TYPE *,' How many brother''s do you have? (0
              ,1,2,3,4,...) '
      ACCEPT *,NBSIB
      CALL CLEAR
C
              IF(NBSIB) 67,77,87
C
87              ICNT=NBSIB+2
                NBRO=1
C
              DO 118 I=3,ICNT
21             TYPE *,' BROTHER NUMBER ',NBRO,' ? '
               TYPE *,''
               TYPE *,'      0=DONT KNOW--PLEASE TE
                            LL EXPERIMENTER'
               TYPE *,'      1=RIGHT HAND'
               TYPE *,'      2=LEFT HAND'
               ACCEPT *,IBFRS(I)
               IF(IBFRS(I).NE.0.AND.IBFRS(I).NE.1.
                AND.IBFRS(I).NE.2)
     1                  GO TO 21
```

```
                  NBRO=NBRO+1
                  CALL CLEAR
 118             CONTINUE
C
C
 77      TYPE *,' How many sister''s do you have? (0,
            1,2,3,4,...)'
         ACCEPT *,NSSIB
         CALL CLEAR
C
                 IF(NSSIB) 77,78,79
C
 79              NCNT=NSSIB+NBSIB+2
                 NSIS=1
C
                 DO 78 J=(NBSIB+3),NCNT
 22               TYPE *,' SISTER NUMBER ',NSIS,' ? '
                  TYPE *,''
                  TYPE *,'          0=DONT KNOW--PLEASE
                            TELL EXPERIMENTER'
                  TYPE *,'          1=RIGHT HAND'
                  TYPE *,'          2=LEFT HAND'
                  ACCEPT *,IBFRS(J)
                  IF(IBFRS(J).NE.0.AND.IBFRS(J).NE.1.
                    AND.IBFRS(J).NE.2)
     1                   GO TO 22
                  NSIS=NSIS+1
                  CALL CLEAR
 78              CONTINUE
C
C
                 IFAM=1
                 NFAM=2+NBSIB+NSSIB
                 DO 500 I=1,NFAM
                 IF(IBFRS(I).EQ.2)IFAM=-1
  500            CONTINUE
C
C
         TYPE 444
 444     FORMAT(//////)
         TYPE*,' Thank you for your cooperation in th
            is part of the'
         TYPE*,' experiment.  Would you now please re
            turn control'
         TYPE*,' of the terminal back to the experime
            nter for the'
         TYPE*,' next part of today''s session. THANK
                YOU.'
         TYPE 444
C
```

```
      PAUSE 'To continue, press RETURN'
      CALL CLEAR
C
C SCORE QUESTIONNAIRE
C
      DO 88 II=1,15
      IF(IRS(II).EQ.2) NLRS=NLRS+1       LEFT
      IF(IRS(II).EQ.1) NRRS=NRRS+1       RIGHT
      IF(IRS(II).EQ.3) NBRS=NBRS+1       BOTH
      IF(IRS(II).EQ.4) NNRS=NNRS+1       NO EXPERIENCE
 88   CONTINUE
C
      NTRS=NRRS-NLRS
C
C WRITE QUESTIONNAIRE DATA TO THE LP
C
      WRITE(2,201)(IRS(I),I=1,15),NTRS
 201  FORMAT(//,1X,'QUESTIONNAIRE RESPONSES: ',15I
      1,2X,'TOTAL: ',I2)
C
      WRITE(2,202)IFAM
 202  FORMAT(//,1X,'FAMILY HANDEDNESS: ',I2)
C
      WRITE(2,203)IBFRS(1)
 203  FORMAT(/,8X,'FATHER: ',I2)
C
      WRITE(2,206)IBFRS(2)
 206  FORMAT(/,8X,'MOTHER: ',I2)
C
      IF(NBSIB.GT.0)WRITE(2,204)(IBFRS(I),I=3,ICNT)
 204  FORMAT(/,6X,'BROTHERS: ',10I2)
C
      IF(NSSIB.GT.0)WRITE(2,205)(IBFRS(I),I=NBSIB+
        3,NCNT)
 205  FORMAT(/,7X,'SISTERS: ',10I2)
C
      REWIND 2
C
C WRITE DATA FOR EXPERIMENTOR
C
      TYPE*,' QUESTIONNAIRE TOTAL: ',NTRS
      TYPE*,''
      TYPE*,'      FAMILY HISTORY: ',IFAM
      IF(NTRS.GE.13.AND.IFAM.EQ.1)
     1 TYPE*,'                              EXPERI
         MENTER: +'
      IF(NTRS.LT.13.OR.IFAM.NE.1)
     1 TYPE*,'                              EXPERI
         MENTER: -'
C
```

```
C
C
        RETURN
        END
C
C
C
                SUBROUTINE CLEAR
C
        II=ITTOUR("033)
        II=ITTOUR("133)
        II=ITTOUR("062)
        II=ITTOUR("112)
        RETURN
        END
C
C
C
                SUBROUTINE CHOICE
C
C THIS IS THE SUBROUTINE WHICH PRODUCES THE DISPLAY
C  OF RESPONSES TO
C  MOST OF THE ITEMS ON THE QUESTIONNAIRE
C
                TYPE *,''
                TYPE*,'               1 = RIGHT HAND'
                TYPE*,'               2 = LEFT HAND'
                TYPE*,'               3 = BOTH HANDS
                      EQUALLY WELL'
                TYPE*,'               4 = NO EXPERIE
                      NCE WITH TASK'
                TYPE *,''
C
                RETURN
                END
C
C
C
C
C
C
C
                SUBROUTINE TASK
C
C THIS IS THE SUBROUTINE WHICH QUERYS THE E FOR THE
C NEXT SECTION, AND
C   THEN DIRECTS PROGRAM CONTROL TO THE APPROPRIATE
C   SUBROUTINE
C
 555    FORMAT(//)
```

```
 5      TYPE 555
        TYPE *,' Enter the number of the test you wa
                 nt to go to :'
        TYPE *,''
        TYPE *,'                      1 = QUESTIONNAIRE.'
        TYPE *,'                      2 = TONE MATCHING.'
        TYPE *,'                      3 = CVCVC NAMING.'
        TYPE *,'                      4 = STOP.'
        ACCEPT *,NTEST
        TYPE 555
        TYPE *,' Please verify that you want to go t
                o:',NTEST
        TYPE *,'                     1 = YES.'
        TYPE *,'                     0 = NO.'
        ACCEPT *,IVRS
        IF(IVRS.NE.1.OR.IVRS.EQ.0) GO TO 5
        IF(NTEST.NE.1.AND.NTEST.NE.2.AND.NTEST.NE.3.
          AND.NTEST.NE.4)
     1    GO TO 5
C
C
                IF(NTEST.EQ.1) GO TO 81
                IF(NTEST.EQ.2) GO TO 82
                IF(NTEST.EQ.3) GO TO 83
                IF(NTEST.EQ.4) GO TO 84
C
  81    CALL QUEST
        GO TO 5
C
  82    CALL TONALN
        GO TO 5
C
  83    CALL CVCVC
        GO TO 5
C
  84    RETURN
        END
C
C
C
C
C
C
                        SUBROUTINE CVCVC
C
        DIMENSION ITRAY1(60),ITRAY2(60),ITRGSTM(60,6
                 ),IIRS(60),IVF(60)
        INTEGER RVFC
        REAL LVFPC
C
```

```
C THIS IS THE SUBROUTINE WHICH PRESENTS TRIALS AND S
C CORES LVF AND RVF
C   PERFORMANCE ON THE CVCVC NAMING TASK.
C
 101    TYPE*,'CVCVC NAMING TASK'
        TYPE*,''
        TYPE*,'How many PRACTICE trials (normally N
              = 10)?'
C
          ACCEPT*,NPRAC
          NPRAC=NPRAC+1           INCREMENT FOR SCORIN
          G PURPOSES
C
        TYPE*,'How many TOTAL trials INCLUDING PRACTICE?'
        TYPE*,'  Normally, 1 tray of 60 trials.'
C
          ACCEPT*,NTRIAL
C
        TYPE*,' Please verify that number of trials
              = ',NTRIAL
        TYPE*,'                       1=YES'
        TYPE*,'                       0=NO'
        ACCEPT*,IVRS
        IF(IVRS.NE.1) GO TO 101
C
C
C
C READ IN TARG STIMS AND VF FOR TRAY1 FROM FILE TARG
C ET.TXT
C
        CALL ASSIGN(18,'TARGET.TXT',10,'OLD','NC')
C
          READ(18,15)(ITRAY1(I),I=1,60)
  15      FORMAT(60A1)
C
          DO 17 I=1,NTRIAL
           READ(18,16)(ITRGSTM(I,J),J=1,6)
  16       FORMAT(6A1)
  17      CONTINUE
C
        CALL CLOSE(18)
C
C ASSIGN VFS TO TRAY 2
C
        DO 20 I=1,NTRIAL
        IF(ITRAY1(I).EQ.1HL) ITRAY2(I)=1HR
        IF(ITRAY1(I).EQ.1HR) ITRAY2(I)=1HL
  20    CONTINUE
C
C GET SOME INFO
```

```
C
  25    TYPE 26
  26    FORMAT(//)
        TYPE *,' Type in EXPOSURE DURATION in msec.'
        TYPE *,' Normally, it will be 130 msec.'
        ACCEPT *,IOPEN
        TYPE *,' Please verify that exposure duratio
     n =',IOPEN
        TYPE *,'                    1 = YES.'
        TYPE *,'                    0 = NO.'
        ACCEPT *,IVRS
        IF(IVRS.EQ.0.OR.IVRS.NE.1) GOTO 25
C
C
 27     TYPE 26
        TYPE 26
        TYPE *,' Which tray will you be presenting?'
        TYPE*,''
        TYPE *,'                    1 = TRAY 1'
        TYPE *,'                    2 = TRAY 2'
        ACCEPT *,ITRS
C
        IF(ITRS.NE.1.AND.ITRS.NE.2) GOTO 27
C
C SET UP SCORING ARRAYS
C
C
        IF(ITRS.EQ.1) GO TO 40
        IF(ITRS.EQ.2) GO TO 50
C
  40    DO 45 I=1,NTRIAL
        IVF(I)=ITRAY1(I)
  45    CONTINUE
C
        GO TO 80
C
  50    DO 55 I=1,NTRIAL
        IVF(I)=ITRAY2(I)
  55    CONTINUE
C
  80    CONTINUE
C
        CALL CLEAR
C
C DO TRIALS
C
        CALL DOUT(0,"7,IERR,"7)
C
        DO 150 II=1,NTRIAL
C
```

```
        IF(II.EQ.1) PAUSE 'PUT ON NEW SLIDE TRAY'
C
          TYPE 26
          TYPE 26
C
C
          PAUSE ' Press ''RETURN'' or ''ENTER'' to s
           tart trial.'
          TYPE 26
          TYPE 85
   85     FORMAT(6H TRIAL,6X,2HVF,6X,4HSTIM)
          TYPE 26
C
C
          TYPE 95,II,IVF(II),(ITRGSTM(II,JJ),JJ=1,6)
   95     FORMAT(3X,I3,7X,A1,8X,6A1)
C
                CALL CLOCKB(,,,IND)                 WAIT
                 1/2 SEC
  100           IF(ICLOKB().LT.500) GOTO 100
C
                IBELL=ITTOUR("007)                  RING
                 BELL
C
                CALL CLOCKB(,,,IND)                 WAIT
                 1 SEC
  110           IF(ICLOKB().LT.1000) GOTO 110
C
                CALL DOUT(0,"4,IERR,"0)             FIXA
                 TION DOT FOR 2 SEC
                CALL CLOCKB(,,,IND)
  120           IF(ICLOKB().LT.2000) GOTO 120
C
                CALL DOUT(0,"6,IERR,"4)             TARG
                  ET TASK SLIDE
                CALL CLOCKB(,,,IND)
  130           IF(ICLOKB().LT.IOPEN) GOTO 130
C
                CALL DOUT(0,"2,IERR,"2)             RESE
                  T SHUTTERS
C
C
  140      TYPE 26
           TYPE*,' Did Subject respond correctly?'
           TYPE*,'  '
           TYPE*,'                    1 = YES.'
           TYPE*,'                    0 = NO.'
           TYPE*,'                    2 = OTHER.'
           ACCEPT *,IIRS(II)
           IF(IIRS(II).NE.0.AND.IIRS(II).NE.1.AND.IIR
```

```
                  S(II).NE.2)
     1               GOTO 140
C
                     CALL DOUT(0,"100,IERR,"100)
                     CALL DOUT(0,"100,IERR,"0)
C
        CALL CLEAR                                   CLEAR SCREEN
C
 150    CONTINUE
C
        IBELL=ITTOUR("007)
        IBELL=ITTOUR("007)
C
C SCORE THE DATA. USE ONLY TRIALS NPRAC-END.
C
        NL=0
        NR=0
        LVFC=0
        RVFC=0
C
        DO 160 I=NPRAC,NTRIAL
        IF(IVF(I).EQ.1HL.AND.IIRS(I).EQ.1) LVFC=LVFC+1
        IF(IVF(I).EQ.1HR.AND.IIRS(I).EQ.1) RVFC=RVFC+1
        IF(IVF(I).EQ.1HL)                  NL=NL+1
        IF(IVF(I).EQ.1HR)                  NR=NR+1
 160    CONTINUE
C
        IF(NL.EQ.0.OR.NR.EQ.0) GO TO 170
        LVFPC=((FLOAT(LVFC))/(FLOAT(NL)))*100.
        RVFPC=((FLOAT(RVFC))/(FLOAT(NR)))*100.
C
        DIFF=RVFPC-LVFPC
C
C TYPE OUT THE DATA TO THE E
C
  170   TYPE 26
        TYPE 26
        TYPE *,' RIGHT VISUAL FIELD:',RVFPC
        TYPE*,''
        TYPE *,'  LEFT VISUAL FIELD:',LVFPC
        TYPE*,''
        TYPE*,'    ****** RVF - LVF:',DIFF
        TYPE*,''
        IF(DIFF.GE.12.)
     1  TYPE*,'                                    EXPERIMEN
          TER: +'
        IF(DIFF.LT.12.)
     1  TYPE*,'                                    EXPERIMEN
          TER: -'
C
C WRITE OUT THE DATA TO THE LP
C
        WRITE(2,171)
 171    FORMAT(///,30X,'CVCVC NAMING')
```

```
C
      WRITE(2,172)RVFC,NR,RVFPC
  172 FORMAT(//,5X,'RVF: ',I2,' OUT OF ',I2,' CORR
     +      ECT = ',F6.2)
C
      WRITE(2,173)LVFC,NL,LVFPC
  173 FORMAT(/ ,5X,'LVF: ',I2,' OUT OF ',I2,' CORR
     +      ECT = ',F6.2)
C
      WRITE(2,174)DIFF
  174 FORMAT(/,5X,'****** RVF-LVF SCORE: ',F6.2)
C
      WRITE(2,175)
  175 FORMAT(///,10X,'RAW DATA')
C
      WRITE(2,176)(IVF(I),I=1,NTRIAL)
  176 FORMAT(/,1X,60A1)
C
      WRITE(2,177)(IIRS(I),I=1,NTRIAL)
  177 FORMAT(/,1X,60I1)
C
      REWIND 2
C
      RETURN
      END
```

```
      PROGRAM HEARD2
C
C
      DIMENSION FNAME(11),INFO(15),ISET(4),ISTIM1(144,5),
     1          ISTIM2(72,3,5),FNAME2(10),FNAME1(11),
     2          IBOX(3,5),FNAME4(9),ISTIM3(72,5)
      COMMON /SCREEN/ICLR(2),IMOV1(4),IMOV2(4),NEWLN(7)
      COMMON /PARAM/NSTIM,NPERTRL,NLET
      BYTE FNAME,FNAME2,FNAME1,FNAME4
      LOGICAL INFO,IBLK
      LOGICAL*1 ICLR,IMOV1,IMOV2,NEWLN,ISTIM1,ISTIM2,IBOX
      LOGICAL*1 ISTIM3
C
      DATA NSTIM,NPERTRL,NLET/222,3,5/
      DATA FNAME/'S','N','N','D','2','R','.','D','A','T',
      DATA FNAME2/'H','2','L','T','1','.','T','X','T',"0/
      DATA FNAME1/'S','N','N','D','2','S',
     1            '.','D','A','T',"0/
      DATA FNAME4/'T','B','O','X','.','D','A','T',"0/
      DATA ICLR/'¬',28/
      DATA IMOV1/'¬',17,39,43/
      DATA IMOV2/'¬',17,37,42/
      DATA NEWLN/'¬',11,8,8,8,8,8/
C
C
C
C
C SET CLOCK OSCILLATING IN MILLISECONDS
C
      CALL CLOCKB(4,-1,,IND)
C
C
      PAUSE 'THINK RANDOM THOUGHTS AND THEN PUSH RETURN'
C
C NOW SET UP HAZELTINE CHARACTERISTICS
C
      I=MTATCH(1,IADR)        1=SLU LINE OF HZLTNE
      ISET(1)="10000
      ISET(4)=80
      I=MTSET(1,ISET)
C
C CLEAR SCREENS
C
      I=MTOUT(1,ICLR,2)
      CALL CLR100
C
C ZERO PAYMENT VARIABLES
C
      ERNTOT=0.0
      BUCKS=0.0
```

```
      ERNBLK=0.0
C
C GATHER A WHOLE BUNCH OF INFORMATION REGARDING THE RUN
C
      TYPE *,''
      TYPE*,'          WELCOME TO HEARD 2'
      TYPE *,''
C
C
      ITRLCNT=1
C
C
C SUBJECT NUMBER IS ACCEPTED AS TWO
C SINGLE-ELEMENT PIECES OF
C   CHARACTER DATA SO THEY CAN BE PLUGGED INTO THE OUTPUT
C   FILENAME.
C
 10   TYPE*,'ENTER SUBJECT NUMBER AS A 2-DIGIT NUMBER'
      ACCEPT 15,ISUB1,ISUB2
 15   FORMAT(2A1)
      TYPE*,'    '
 20   TYPE 25,ISUB1,ISUB2
 25   FORMAT('CONFIRM THAT THIS IS SUBJECT
              NUMBER: ',2A1)
      TYPE*,'    '
      TYPE*,'                        1=YES'
      TYPE*,'                        0=NO'
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0) GO TO 20
      IF(IANS.NE.1) GO TO 10
      CALL CLR100
C
C OPEN THE FILES
C
      FNAME(2)=ISUB1
      FNAME(3)=ISUB2
      OPEN(UNIT=8,NAME=FNAME,TYPE='NEW')
      FNAME1(2)=ISUB1
      FNAME1(3)=ISUB2
      OPEN(UNIT=9,NAME=FNAME1,TYPE='NEW')
C
C
C ACCEPT SUBJECT ORDER (FROM 1-2)
C
 30   TYPE*,'ENTER ORDER FOR THIS SUBJECT'
      TYPE*,'    '
      TYPE*,'               1 = CVCVC EMPHASIS FIRST'
      TYPE*,'               2 = TONE EMPHASIS FIRST'
      ACCEPT 35,IORD
```

```
 35   FORMAT(A1)
      IF(IORD.NE.'1'.AND.IORD.NE.'2')GO TO 30
 40   TYPE*,'  '
      TYPE 45,IORD
 45   FORMAT(' IS THE CORRECT ORDER ',A1,'?')
      TYPE*,'  '
      TYPE*,'      1=YES'
      TYPE*,'      0=NO'
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0) GO TO 40
      IF(IANS.NE.1) GO TO 30
      CALL CLR100
C
C CONDITION # IS DETERMINED
C
  50  TYPE*,'WHICH CONDITION IS NEXT?'
      TYPE*,'  '
      TYPE*,'      1 = CVCVC ALONE'
      TYPE*,'      2 = TONES ALONE'
      TYPE*,'      3 = DUAL CVCVC EMPH'
      TYPE*,'      4 = DUAL  TONE EMPH'
      TYPE*,'      0 = NO CONDITION - STOP HERE'
      ACCEPT 35,ICOND
  60  TYPE*,'  '
      TYPE 65,ICOND
  65  FORMAT(' CONFIRM THAT YOU WANT CONDITION ',A1)
      TYPE*,'  '
      TYPE*,'     1=YES'
      TYPE*,'     0=NO'
      TYPE*,'  '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 60
      IF(IANS.NE.1) GO TO 50
      IF(ICOND.EQ.'0')GO TO 1000
      CALL CLR100
C
C
C TO DETERMINE WHICH LIST IS WANTED
C
 66   TYPE*,'WHICH CVCVC LIST DO YOU WANT ?'
      TYPE*,' '
      TYPE*,'     1 =CVCALN LIST1  '
      TYPE*,'     2 =CVCALN LIST2  '
      TYPE*,'     3 =DUAL   LIST1  '
      TYPE*,'     4 =DUAL   LIST2  '
      ACCEPT 35,ILIST
 67   TYPE 69,ILIST
 69   FORMAT(' CONFIRM THAT YOU WANT LIST',A1)
      TYPE*,'  '
```

```
      TYPE*,'      1=YES  '
      TYPE*,'      0=NO   '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 67
      IF(IANS.NE.1)GO TO 66
      CALL CLR100
C
 71   TYPE*,' WHICH TAPE ARE YOU RUNNING FOR THIS?'
      TYPE*,''
      TYPE*,'      1=TAPE ONE  '
      TYPE*,'      2=TAPE TWO  '
      TYPE*,'      3=TAPE THREE'
      TYPE*,'      4=TAPE FOUR '
      ACCEPT*,ITAPE
      TYPE*,' CONFIRM THAT YOU WANT TAPE',ITAPE
      TYPE*,''
      TYPE*,'      1=YES  '
      TYPE*,'      0=NO   '
      ACCEPT*,IANS
      IF(IANS.NE.1)GO TO 71
      CALL CLR100
C
C
      FNAME2(5)=ILIST
      OPEN(UNIT=11,NAME=FNAME2,TYPE='OLD')
      CALL CLR100
C-------------------------------------------------------
C TO READ STIMS FROM ILIST INTO AN ARRAY.
C
      IF(ILIST.EQ.'1'.OR.ILIST.EQ.'2')GO TO 12
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
C
```

```
C
C (1). DUAL STIMULI LISTS.
        DO 8 I=1,144
         READ(11,7)(ISTIM1(I,J),J=1,NLET)
  7      FORMAT(5A1)
  8     CONTINUE
        GO TO 13
C
C
  12    CONTINUE
C
C (2). CVCALN STIM LISTS.
C
        DO 11 I=1,72
         READ(11,7)(ISTIM3(I,J),J=1,NLET)
  11    CONTINUE
C
  13    CONTINUE
C
        CALL CLOSE(11)
C
C-----------------------------------------------------
C TO OPEN FILE WITH BOX FOR TONALN TRIALS AND TO
C ENTER THE BOX INTO AN ARRAY IBOX(I,J).
C
        OPEN(UNIT=13,NAME=FNAME4,TYPE='OLD')
         DO 500 I=1,3
          READ(13,505)(IBOX(I,J),J=1,5)
 505      FORMAT(5A1)
 500     CONTINUE
        CALL CLOSE(13)
C
C------------------------------------------------------
C
C FIGURE OUT EMPHASIS
C
        IF(ICOND.EQ.'1'.OR.ICOND.EQ.'2') IEMPH='0'    ALONE
        IF(ICOND.EQ.'3')                 IEMPH='1'    CVCVC
        IF(ICOND.EQ.'4')                 IEMPH='2'    TONES
C
C
C
 70     TYPE*,'WHICH BLOCK IS TO BE RUN ?'
        TYPE*,''
        TYPE*,'   1=CVCVC ALN - EMPH 1'
        TYPE*,'   2=TONE  ALN - EMPH 1'
        TYPE*,'   3=DUAL      - EMPH 1'
        TYPE*,'                       '
        TYPE*,'   4=CVCVC ALN - EMPH 2'
        TYPE*,'   5=TONE  ALN - EMPH 2'
        TYPE*,'   6=DUAL      - EMPH 2'
        ACCEPT 35,IBLK
```

```
      TYPE*,''
      TYPE 72,IBLK
 72   FORMAT(' CONFIRM THAT YOU WANT BLOCK',A1)
      TYPE*,''
      TYPE*,'      1=YES'
      TYPE*,'      0=NO'
      TYPE*,'  '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 70
      IF(IANS.NE.1)GO TO 70
      CALL CLR100
C
C DETERMINE # OF TRIALS FOR THE PRESENT BLOCK
C
      IF(ICOND.EQ.'1')NTRIALS=24
      IF(ICOND.EQ.'2')NTRIALS=48
      IF(ICOND.EQ.'3')NTRIALS=48
      IF(ICOND.EQ.'4')NTRIALS=48
C
 80   TYPE*,'  '
      TYPE*,'YOU WANT TO RUN',NTRIALS,'
             TRIALS FOR THIS BLOCK?'
      TYPE*,'  '
      TYPE*,'       1=YES'
      TYPE*,'       0=NO'
      TYPE*,'   '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 80
      IF(IANS.NE.1)TYPE*,'HOW MANY TRIALS FOR
                     THIS BLOCK?'
      IF(IANS.NE.1)ACCEPT*,NTRIALS
      CALL CLR100
C
C
      IEAR=2
      IF(ICOND.EQ.'1')GO TO 86
C
 85   TYPE*,'WHICH EAR IS THE CORD ON?'
      TYPE*,'  '
      TYPE*,'       0=LEFT EAR'
      TYPE*,'       1=RIGHT EAR'
      TYPE*,'  '
      ACCEPT*,IEAR
      IF(IEAR.NE.1.AND.IEAR.NE.0)GO TO 85
      IF(IEAR.EQ.0)IEER='0'
      IF(IEAR.EQ.1)IEER='1'
      CALL CLR100
C
 82   TYPE*,' DO YOU WANT THIS BLOCK WITH EAR',IEAR
      TYPE*,''
```

```
      TYPE*,'      1=YES  '
      TYPE*,'      0=NO    '
      ACCEPT*,IANS
      IF(IANS.NE.0.AND.IANS.NE.1)GO TO 82
      IF(IANS.NE.1)GO TO 85
      CALL CLR100
C
C
 86   TYPE*,'WHICH SET OF TRIALS FOR THIS CONDITION?'
      TYPE*,'       '
      TYPE*,'   1=SET 1:  (01  TO 20)  (CVCVC ALONE1)'
      TYPE*,'   2=SET 2:  (21  TO 40)  (TONALN1 EAR ?)'
      TYPE*,'          :  (41  TO 60)  (TONALN1 EAR ?)'
      TYPE*,'   3=SET 3:  (61  TO 80)  (DUAL1 EAR ?)'
      TYPE*,'          :  (81  TO 100) (DUAL1 EAR ?)'
      TYPE*,''
      TYPE*,'----------------------------------------'
      TYPE*,''
      TYPE*,'   4=SET 4:  (101 TO 120) (CVCVC ALONE2)'
      TYPE*,'   5=SET 5:  (121 TO 140) (TONALN2 EAR ?)'
      TYPE*,'          :  (141 TO 160) (TONALN2 EAR ?)'
      TYPE*,'   6=SET 6:  (161 TO 180) (DUAL2 EAR ?)'
      TYPE*,'          :  (181 TO 200) (DUAL2 EAR ?)'
      TYPE*,'                  '
      ACCEPT*,ITSET
      IF(ITSET .LT.1 .OR. ITSET .GT.6)GO TO 86
C
 78   TYPE*,'DO YOU WANT SET',ITSET
      TYPE*,''
      TYPE*,'    1=YES'
      TYPE*,'    0=NO '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 78
      IF(IANS.NE.1)GO TO 86
      CALL CLR100
C
C
C SET VALUES OF INFO (TO BE PASSED)
C
 87   CONTINUE
C
C
      INFO(1)='S'
      INFO(2)=ISUB1
      INFO(3)=ISUB2
      INFO(4)='O'
      INFO(5)=IORD
      INFO(6)='C'
      INFO(7)=ICOND
      INFO(8)='B'
```

```
      INFO(9)=IBLK
      INFO(10)='E'
      INFO(11)='M'
      INFO(12)=IEMPH
      INFO(13)='E'
      INFO(14)=IEER
C
C ZERO VARIABLES FOR PERCENT CORRECT.
C
      PCORL=0.0
      PCORR=0.0
      HITL=0.0
      HITR=0.0
      MISSL=0
      MISSR=0
      CRL=0.0
      CRR=0.0
      FAL=0.0
      FAR=0.0
      NRECL=0
      NRECR=0
      NRECML=0
      NRECMR=0
      NRECCL=0
      NRECCR=0
      NRECFL=0
      NRECFR=0
      NRECFA=0
      NRECCR=0
      NTREC=0
      NTON=0
      ITON=0
C
C GET THE CVCVC'S READY IF NECESSARY:
      IF(ICOND.EQ.'2')GO TO 105
C
      ITRLCNT=1
      IF(ILIST.EQ.'1'.OR.ILIST.EQ.'2')GO TO 99
C (1). DUAL TASK STIMS.
      DO 90 I=1,48
       DO 89 J=1,NPERTRL
        DO 88 K=1,NLET
         ISTIM2(I,J,K)=ISTIM1(ITRLCNT,K)
 88     CONTINUE
        ITRLCNT=ITRLCNT+1
 89    CONTINUE
 90   CONTINUE
      GO TO 105
C
 99   CONTINUE
```

```
C
C (2). CVCALN TASK STIMS.
       DO 104 I=1,24
        DO 103 J=1,NPERTRL
         DO 102 K=1,NLET
          ISTIM2(I,J,K)=ISTIM3(ITRLCNT,K)
 102     CONTINUE
         ITRLCNT=ITRLCNT+1
 103    CONTINUE
 104   CONTINUE
C
C
 105   CONTINUE
C
C------------------------------------------------------------
C
       DO 120 ITRL=1,NTRIALS
C
        IF(ICOND.EQ.'1') GO TO 91
        IF(ICOND.EQ.'2') GO TO 100
        IF(ICOND.EQ.'3'.OR.ICOND.EQ.'4') GO TO 110
C
  91    CALL H2CVC(INFO,ITRL,ISTIM2,NREC,ITSET,NTREC)
        CALL H2PAY(ICOND,IEMPH,ITRL,NREC,
                   ITON,ERNTOT,ERNBLK)
        GO TO 120
C
 100    CALL H2TONE(INFO,ITRL,IEAR,ITSET,
                    HITL,HITR,MISSL,MISSR,
     1         CRL,CRR,FAL,FAR,ITON,IBOX,ITAPE)
        CALL H2PAY(ICOND,IEMPH,ITRL,NREC,
                   ITON,ERNTOT,ERNBLK)
        GO TO 120
C
 110    CALL H2DUA(INFO,ITRL,NREC,CORL,CORR,NRECL,
                   NRECR,NRECML,NRECMR,
     1            NRECCR,IEAR,ITSET,ISTIM2,NTON,
                   ITON,NRECCL,NRECFR,
     2            NRECFL,HITL,HITR,MISSL,MISSR,CRL,
                   CRR,FAL,FAR,ITAPE)
        CALL H2PAY(ICOND,IEMPH,ITRL,NREC,ITON,ERNTOT,
                    ERNBLK)
 120   CONTINUE
C
C
C-----------------------------------------------------------------
C
       WRITE(9,400)(INFO(J),J=1,14)
 400   FORMAT(2X,14A1)
C
```

```
C
         IF(ICOND.EQ.'2')GO TO 132
         IF(ICOND.EQ.'1')GO TO 140
C
C---------------------------------------------------------------------
C THE FOLLOWING CALCULATIONS ARE FOR THE DUAL CONDITIONS.
C
         CORR=CORR/20.*100
         CORL=CORL/20.*100
         PERALL=(CORR+CORL)/2
         TYPE*,' CORRECT RIGHT EAR:',CORR
         TYPE*,' CORRECT LEFT EAR: ',CORL
C
C
 410     FORMAT(/)
C
C
         WRITE(9,410)
         WRITE(9,121)IEMPH,ITSET
  121    FORMAT(2X,'DUAL TASK RESULTS: EMPHASIS
                NUMBER',1X,A1,
     1         'SET ',I2)
C
C---------------------------------------
C LEFT EAR TARGET:
C
         WRITE(9,419)
 419     FORMAT(2X,'LEFT EAR  TARGET DATA - LOAD DATA')
C
         WRITE(9,420)HITL,MISSL,CRL,FAL,CORL
 420     FORMAT(2X,'HITL',4X,'MISSL',4X,'COR-REJL',
                4X,'FAL',4X,
     1         'PER CORL',/,2X,F3.0,5X,I3,7X,F3.0,6X,
                           F3.0,7X,F6.2)
C
         WRITE(9,440)NRECL,NRECML,NRECCL,NRECFL
 440     FORMAT(2X,I3,5X,I3,7X,I3,6X,I3)
C
C---------------------------------------
C RIGHT EAR TARGET:
C
         WRITE(9,125)
 125     FORMAT(2X,'RIGHT EAR TARGET DATA - LOAD DATA')
C
         WRITE(9,430)HITR,MISSR,CRR,FAR,CORR
 430     FORMAT(2X,'HITR',4X,'MISSR',4X,'COR-REJR',4X
                ,'FAR',4X,
     1         'PER CORR',/,2X,F3.0,5X,I3,7X,F3.0,6X,
                           F3.0,7X,F6.2)
C
         WRITE(9,440)NRECR,NRECMR,NRECCR,NRECFR
C
C---------------------------------------
C EARNINGS:
```

```
C
         WRITE(9,444)IEMPH,ERNBLK
  444    FORMAT(2X,'TOTAL EARNINGS AT END OF DUAL TAS
               K EMPHASIS ',
     1         A1,' ARE',F8.3)
C
C
         WRITE(9,129)IEMPH,ERNTOT
  129    FORMAT(2X,'TOTAL EARNINGS THUS FAR',1X,A1,
     1         ' ARE',F8.3)
C
         GO TO 150
C
C-----------------------------------------------------------
C
  132    CONTINUE
C
C
C THE FOLLOWING IS FOR THE TONE ALONE CONDITIONS:
C FIRST THE LEFT EAR TONALN CONDITION.
C
C
         WRITE(9,560)ITSET
 560     FORMAT(2X,'RESULTS FOR TONALN: SET ',I2)
C
         WRITE(9,410)
C
         WRITE(9,190)
  190    FORMAT(2X,'RESULTS FOR LEFT EAR')
C
C
         PCORL=(HITL+CRL)/20*100
C
C
         WRITE(9,133)HITL,MISSL,CRL,FAL,PCORL
  133    FORMAT(2X,'HIT',5X,'MISS',5X,'COR-REJ',5X,'F
               A',5X,'PER COR',/,
     1         2X,F3.0,5X,I3,7X,F3.0,6X,F3.0,7X,F8.3)
C
C----------------------------------
C FOR RIGHT EAR TONALN CONDITION:
C
  199    PCORR=(HITR+CRR)/20*100
C
         WRITE(9,410)
C
```

```
       WRITE(9,451)
 451   FORMAT(2X,'RESULTS FOR RIGHT EAR')
C
       WRITE(9,210)HITR,MISSR,CRR,FAR,PCORR
  210  FORMAT(2X,'HIT',5X,'MISS',5X,'COR-REJ',5X,'F
              A',5X,'PER COR',/,
     1        2X,F3.0,5X,I3,7X,F3.0,6X,F3.0,7X,F8.3)
C
       WRITE(9,410)
C
       WRITE(9,215)ERNBLK
  215  FORMAT(2X,'BLOCK EARNINGS AT END OF TONE ALO
              NE ',F8.3)
C
C
       WRITE(9,410)
C
       WRITE(9,220)ERNTOT
  220  FORMAT(2X,'TOTAL EARNINGS THUS FAR ARE ',F8.3)
C
C
       GO TO 150
C
C-------------------------------------------------------
C
  140  CONTINUE
C-------------------------------------------------
C THE FOLLOWING IS FOR THE CVCVC CONDITION ALONE:
C
       WRITE(9,123)ITSET
  123  FORMAT(2X,//,'RESULTS FOR CVCVC ALONE: SET ',I2)
C
C
       WRITE(9,141)NTREC
  141  FORMAT(2X,'THE NUMBER OF CVCVC RECALLED',I3)
C
       WRITE(9,565)ERNBLK
 565   FORMAT(2X,'BLOCK EARNINGS FOR CVCVC ALONE AR
               E ',F8.3)
C
       WRITE(9,142)ERNTOT
  142  FORMAT(2X,'THE TOTAL EARNINGS AT END OF CVC
               ALONE',1X,F8.3)
C
C-------------------------------------------------------
C
C PROGRAM CONTROL IS NOW SENT BACK UP TO WHERE CONDI
C TION # IS
C   DETERMINED TO SEE IF ANOTHER CONDITION SHOULD BE RUN
C
```

```
  150     CONTINUE
C
          GO TO 50
C
C
C MAKE SURE THAT THE E HASN'T BOO-BOO-ED OR CHANGED
C HIS/HER MIND
C
 1000     TYPE*,'     '
          TYPE*,'ARE YOU SURE YOU WANT TO STOP?'
          TYPE*,'     '
          TYPE*,'          1=YES'
          TYPE*,'          0=NO'
          TYPE*,'    '
          ACCEPT*,IANS
          IF(IANS.NE.1.AND.IANS.NE.0)GO TO 1000
          IF(IANS.EQ.0) GO TO 50
C
C WRITE OUT TOTAL EARNINGS
C
          TYPE *,''
          TYPE*,'THE TOTAL EARNINGS FOR THIS EXP. WERE
                :',ERNTOT
          TYPE*,'    '
          BUCKS=ERNTOT
          TYPE*,'THE SUBJECT EARNED ',BUCKS,' FOR THIS
                  EXPERIMENT'
C
C WRITE A SENTINAL
C
          WRITE(8,135)
 135      FORMAT('999999999999999',60X)
C
          CALL CLOSE(8)
C
C UNPAUSE RECORDER
C
          CALL DOUT(0,"20000,IERR,"0)
C
          STOP
          END
C
C
C
C
C
          SUBROUTINE CLR100
C
          I=ITTOUR("033)
          I=ITTOUR("133)
```

```
        I=ITTOUR("062)
        I=ITTOUR("112)
C
        RETURN
        END
C
C
C
C
                SUBROUTINE H2TONE(INFO,ITRL,IEAR,
                                   ITSET,HITL,HITR,
     1         MISSL,MISSR,CRL,CRR,FAL,FAR,ITON,IBOX,ITAPE)
C
        DIMENSION INFO(15),ISTIM1(10),IDIGIT(10),
                  ICOR(192),IBOX(3,5)
        COMMON/SCREEN/ICLR(2),IMOV1(4),IMOV2(4),NEWLN(4)
        LOGICAL INFO
        LOGICAL*1 ICLR,IMOV1,IMOV2,NEWLN,IBOX
        DATA NSTIM,IBELL/5,"007/
        DATA ICOR/0,1,1,0,0,0,1,0,1,1,0,1,0,1,0,0,1,
                  1,0,1,0,0,1,1,
     1            0,1,1,0,0,0,1,0,1,1,0,1,0,1,0,0,1,
                  1,0,1,0,0,1,1,
     2            1,0,1,0,1,0,1,1,0,1,0,0,1,0,0,1,0,
                  1,1,0,1,0,1,0,
     3            1,0,1,0,1,0,1,1,0,1,0,0,1,0,0,1,0,
                  1,1,0,1,0,1,0,
     4            1,0,0,1,1,0,0,1,0,0,1,0,1,1,1,0,1,
                  1,0,0,1,0,0,1,
     5            1,0,0,1,1,0,0,1,0,0,1,0,1,1,1,0,1,
                  1,0,0,1,0,0,1,
     6            0,0,1,1,0,0,1,1,0,1,0,0,1,1,0,0,0,
                  1,1,1,0,1,0,1,
     7            0,0,1,1,0,0,1,1,0,1,0,0,1,1,0,0,0,
                  1,1,1,0,1,0,1/
C
C CLEAR SCREEN
C
        II=MTOUT(1,ICLR,2)
C
C
C TO CHECK IF MUST CHANGE EARS.
C
        IF(ITRL.NE.25)GO TO 4
        IF(IEAR.EQ.0)ICHGE=1
        IF(IEAR.EQ.1)ICHGE=0
        IEAR=ICHGE
   2    TYPE*,'TELL SUBJECT TO REVERSE THE HEADPHONES'
        TYPE*,''
        TYPE*,''
   3    TYPE*,'HAS THE SUBJECT REVERSED THE HEADPHONES ?'
        TYPE*,''
```

```
      TYPE*,'       1=YES  '
       TYPE*,'       0=NO   '
       ACCEPT*,IANS
       IF(IANS.NE.1.AND.IANS.NE.0)GO TO 3
       IF(IANS.NE.1)GO TO 2
C
C
  4    NTRIAL=ITRL
       IJMP=0
       IF(ITSET.EQ.5)NTRIAL=ITRL+120
       IF(ITRL.LE.4.OR.ITRL.GE.25.AND.ITRL.LE.28)GO TO 5
       IF(ITRL.LE.25)NTRIAL=NTRIAL-4
       IF(ITRL.GT.25)NTRIAL=NTRIAL-8
       IJMP=1
  5    TYPE*,'TRIAL NUMBER',NTRIAL
C
       PAUSE 'PUSH RETURN TO START TRIAL'
       CALL CLR100
C
C START RECORDER
C
       CALL CLOCKB(,,,IND)
  6    CALL DOUT(0,"20000,IERR,"0)
       IF(ICLOKB().LT.20)GO TO 6
  7    CALL DOUT(0,"20000,IERR,"20000)
       IF(ICLOKB().LT.40)GO TO 7
C
C
 9     IF (ICLOKB().LE.500)GO TO 9
C
C WAIT FOR WARNING TONE
C
  10   IF(IDINP(0,"100000,IERR,INPUT).EQ.0) GO TO 10
       TYPE*,' WARNING TONE'
C
C
       DO 11 I=1,3
       TYPE 13,(IBOX(I,J),J=1,5)
  13   FORMAT(5A1)
  11   CONTINUE
C
C CLEAR SCREEN AND MOVE CURSOR TO CENTER.
C
       II=MTOUT(1,ICLR,2)
       II=MTOUT(1,IMOV1,4)
C
C
C ZERO CLOCK AND WAIT 500 MSECS
C
       CALL CLOCKB(,,,IND)
 20    IF(ICLOKB().LE.500)GO TO 20
C
```

```
C CLEAR SCREEN AND PRESENT BOX.
C
        II=MTOUT(1,ICLR,2)
        CALL H2TBOX(IBOX)
C
C WAIT 2500 MSEC AND THEN CLEAR SCREEN.
C
        CALL CLOCKB(,,,IND)
 25     IF(ICLOKB().LE.2500)GO TO 25
        II=MTOUT(1,ICLR,2)
C
C
C DETECT BOTH TONE PAIRS
C
 40     IF(IDINP(0,"100000,IERR,INPUT).EQ.0) GO TO 40
 50     IF(IDINP(0,"100000,IERR,INPUT).NE.0) GO TO 50
        TYPE*,' TONE 1 OFFSET'
C
 60     IF(IDINP(0,"100000,IERR,INPUT).EQ.0) GO TO 60
 70     IF(IDINP(0,"100000,IERR,INPUT).NE.0) GO TO 70
        TYPE*,' TONE 2 OFFSET'
C
C STOP RECORDER
C
        CALL CLOCKB(,,,IND)
 71     CALL DOUT(0,"20000,IERR,"0)
        IF(ICLOKB().LT.20)GO TO 71
 72     CALL DOUT(0,"20000,IERR,"20000)
        IF(ICLOKB().LT.40)GO TO 72
C
C WAIT FOR MUSIC RESPONSE
C
        CALL DOUT(0,"100000,IERR,"0)
        CALL DOUT(0,"100000,IERR,"100000)
  80    IF(IDINP(0,"17,IERR,INPUT).EQ.0) GO TO 80
C
C PRESENT FIXATION DOT AFTER MUSIC RESPONSE
C
        II=MTOUT(1,IMOV1,4)
C
C IF IS A PRACTICE SET WANT TO SKIP SCORING.
C
        IF(IJMP.EQ.0)GO TO 200
C
C SCORE RESPONSE
C
        IF(INPUT.EQ.2.OR.INPUT.EQ.4) IRESP=1     YES
        IF(INPUT.EQ.1.OR.INPUT.EQ.8) IRESP=0     NO
C
C
C TO MATCH THE RESPONSE (YES=0/NO=1) TO DATA ARRAY
C ICOR AND IEAR:
```

```
C
C NOTE: THE KEY IS AS FOLLOWS:
C        ITRLR=00 IS A HIT   LEFT EAR
C        ITRLR=02 IS A MISS  LEFT EAR
C        ITRLR=04 IS A CR    LEFT EAR
C        ITRLR=07 IS A FA    LEFT EAR
C        ITRLR=10 IS A HIT   RIGHT EAR
C        ITRLR=12 IS A MISS  RIGHT EAR
C        ITRLR=14 IS A CR    RIGHT EAR
C        ITRLR=17 IS A FA    RIGHT EAR
C
         IFAKE=ITRL
         ITRLR=25
         IF(ITAPE.EQ.2)ITRL=ITRL+48
         IF(ITAPE.EQ.3)ITRL=ITRL+96
         IF(ITAPE.EQ.4)ITRL=ITRL+144
C
C (1) FIRST THE YES RESPONSES GIVING ONE OF TWO HITS:
C
         IF(IRESP .EQ. 0)GO TO 100
         IF(IRESP .EQ. ICOR(ITRL).AND.IEAR.EQ.0)ITRLR=0
         IF(IRESP .EQ. ICOR(ITRL).AND.IEAR.EQ.1)ITRLR=10
         IF(ITRLR.EQ.0)HITL=HITL+1
         IF(ITRLR.EQ.10)HITR=HITR+1
         IF(ITRLR.NE.25)GO TO 110
 99      GO TO 105
C
C FOR THE "NO" RESPONSES HAVE MISSES AND CR'S.
C
 100     IF(ICOR(ITRL).EQ.1.AND.IEAR.EQ.0)ITRLR=2
         IF(ICOR(ITRL).EQ.1.AND.IEAR.EQ.1)ITRLR=12
         IF(ITRLR.EQ.2)MISSL=MISSL+1
         IF(ITRLR.EQ.12)MISSR=MISSR+1
         IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.0)ITRLR=4
         IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.1)ITRLR=14
         IF(ITRLR.EQ.4)CRL=CRL+1
         IF(ITRLR.EQ.14)CRR=CRR+1
         GO TO 110
C
C
 105     CONTINUE
C
C TO COMPUTE THE FA'S.
C
         IF(IEAR.EQ.0)ITRLR=7
         IF(IEAR.EQ.1)ITRLR=17
         IF(ITRLR.EQ.7)FAL=FAL+1
         IF(ITRLR.EQ.17)FAR=FAR+1
C
 110     CONTINUE
         ITON=0
         IF(ITRLR.EQ.0.OR.ITRLR.EQ.4)ITON=1
```

```
      IF(ITRLR.EQ.10.OR.ITRLR.EQ.14)ITON=1
C
      ITRL=IFAKE
C
C-----------------------------------------------------------------
C TO WRITE THE RESPONSE TO THE FILE:
C
      WRITE(8,90)(INFO(J),J=1,14),NTRIAL,IRESP,ITRLR
 90   FORMAT(14A1,3X,'T',I3,3X,'RESP',I1,3X,'SCORE',I2)
C-----------------------------------------------------------------
 200  CONTINUE
C
C WISH TO REMOVE FIXATION DOT FROM SCREEN AFTER 2 SEC.
C
      CALL CLOCKB(,,,IND)
  250 IF(ICLOKB().LE.2000)GO TO 250
      CALL CLR100
C
C
      RETURN
      END
C
C
C
C
              SUBROUTINE H2CVC(INFO,ITRL,ISTIM2,NREC,
                                 ITSET,ISET,
     1                                 NTREC)
C
      DIMENSION INFO(15),ISTIM2(72,3,5)
      COMMON/SCREEN/ICLR(2),IMOV1(4),IMOV2(4),NEWLN(7),
     1               ISTR1(41),ISTR2(40)
      COMMON /PARAM/NSTIM,NPERTRL,NLET
C
      LOGICAL*1 ICLR,IMOV1,IMOV2,NEWLN,ISTR1,ISTR2,ISTIM2
      LOGICAL INFO
      DATA IBELL/"007/
C
C SCREEN IS CLEARED
C
      II=MTOUT(1,ICLR,2)
C
      TYPE 5
    5 FORMAT(//)
      PAUSE 'TO INITIATE TRIAL PRESS RETURN'
      ISET=0
C
      IF(ITRL.GE.1.AND.ITRL.LE.4)ISET=50
C
C
      NTRL=ITRL
      IF(ISET.NE.50)NTRL=ITRL-4
```

```
      ICVC=ITRL
      IF(ITSET.NE.1)NTRL=NTRL+100
C
C
      CALL CLR100
      TYPE*,' THE STIMS FOR TRIAL',NTRL,'ARE:'
      TYPE*,'  '
C
      DO 20 J=1,NPERTRL
       TYPE 15,(ISTIM2(ICVC,J,K),K=1,NLET)
 15    FORMAT(35X,5A1)
 20   CONTINUE
C
C CLOCK IS ZEROED, AND BELL IS RUNG AFTER 1/2 SECOND
C
      CALL CLOCKB(,,,IND)
 30   IF (ICLOKB().LT.500) GO TO 30
      II=MTOUT(1,IBELL,1)
C
C MOVE THE CURSOR TO THE CENTER
C
      II=MTOUT(1,IMOV1,4)
C
C CLOCK IS ZEROED ONCE AGAIN TO COMMENCE TIMING
C
      CALL CLOCKB(,,,IND)
C
C
      IFLAG1=0
      IFLAG2=0
C
  40  IF(ICLOKB().LT. 500) GO TO 40
      CALL H2DISP(IFLAG1,ISTIM2,ITRL)
C
  50  IF(ICLOKB().LT.3000) GO TO 50
      CALL H2CLR(IFLAG2)
C
  60  IF(ICLOKB().LE.9000) GO TO 60
C
C SIGNAL TO SUBJECT THE END OF THE TRIAL WITH ONE BEEP
C AND A FIXATION DOT IS GIVEN.
C
      II=MTOUT(1,IBELL,1)
      II=MTOUT(1,IMOV1,4)
C
C NOW THE NUMBER OF RECALLED WORDS IS OBTAINED FROM THE E
C
  65  TYPE*,'HOW MANY CVCVCS DID THE SUBJECT RECALL?'
      TYPE*,'   '
      ACCEPT*,NREC
      IF(NREC.GT.3) GO TO 65
      TYPE*,'   '
```

```
        TYPE*,'THE SUBJECT RECALLED',NREC,'CVCVCS.  TRUE?'
        TYPE*,'    '
        TYPE*,'    1=YES'
        TYPE*,'    0=NO'
        ACCEPT*,IANS
        IF(IANS.NE.1.AND.IANS.NE.0) GO TO 65
        IF(IANS.NE.1) GO TO 65
        CALL CLR100
        NTREC=NTREC+NREC
C
C CLEAR SCREEN
C
        II=MTOUT(1,ICLR,2)
C
C WRITE THE RAW DATA TO FILES
C
        IF(ISET.EQ.50)GO TO 80
        WRITE(8,75)(INFO(J),J=1,14),NTRL,NREC
  75    FORMAT(14A1,3X,'T',I2,22X,'NREC',I2)
C
C
        IF(ISET.NE.50)NTRL=NTRL+4
  80    IF(ITSET.NE.1)NTRL=NTRL-100
C
 1000   RETURN
        END
C
C
C
C
                SUBROUTINE H2DISP(IFLAG1,ISTIM2,ITRL)
C
C THIS SUBROUTINE IS USED FOR THE DISPLAYING OF STIMS
C ON THE HAZELTINE
C IN THE CVCVC NAMING TASK OF HEARD2.
C
        COMMON/SCREEN/ICLR(2),IMOV1(4),IMOV2(4),NEWLN(7)
        DIMENSION ISTIM2(72,3,5),IMOV3(2)
        LOGICAL*1 ICLR,IMOV1,IMOV2,IMOV3,NEWLN,ISTIM2
        DATA IMOV3/16,16/
        COMMON /PARAM/NSTIM,NPERTRL,NLET
C
        IFLAG1=1
C
        II=MTOUT(1,IMOV2,4)
C
        DO 10 I=1,NPERTRL
         DO 5 J=1,NLET
          II=MTOUT(1,ISTIM2(ITRL,I,J),1)
  5      CONTINUE
         II=MTOUT(1,NEWLN,7)
  10    CONTINUE
```

```
C
      II=MTOUT(1,IMOV3,2)
C
      RETURN
      END


      SUBROUTINE H2PAY(ICOND,IEMPH,ITRL,NREC,ITON,
                       ERNTOT,ERNBLK,
     1                 ISET)
C
C
C THIS SUBROUTINE COMPUTES THE NUMBER OF POINTS EARN
C ED FOR THE
C  VARIOUS TASKS IN THE EXPERIMENT HEARD2.
C
      LOGICAL ICOND
C
C SET PAYOFFS
C
      DATA CVCALN/.05/   CVCVC ALONE
      DATA TONALN/.05/   TON ALONE
      DATA CVCDL1/.04/   CVC PAYOFF - DUAL CVC  EMPH
      DATA CVCDL2/.01/   CVC PAYOFF - DUAL TONE EMPH
      DATA TONDL1/.01/   TON PAYOFF - DUAL CVC  EMPH
      DATA TONDL2/.04/   TON PAYOFF - DUAL TONE EMPH
C
      IF(ITRL.NE.1.OR.ITRL.NE.26.OR.ITRL.NE.75)GO TO 8
      IF(ITRL.NE.123.OR.ITRL.NE.149.OR.ITRL.NE.198)GOTO8
      ERNBLK=0.0
 5    FORMAT(/)
C
C DETERMINE CONDITION
C
 8    IF(ITRL.GE.1.AND.ITRL.LE.4)GO TO 50
      IF(ITRL.GE.25.AND.ITRL.LE.28)GO TO 50
      IF(ICOND.EQ.'1') GO TO 10       cvcvc alone
      IF(ICOND.EQ.'2') GO TO 20       ton alone
      IF(ICOND.EQ.'3') GO TO 30       dual - cvcvc emphasis
      IF(ICOND.EQ.'4') GO TO 40    dual - ton   emphasis
C
 10   IF(NREC.NE.3)GO TO 12
      ERNTRL=CVCALN
      GO TO 13
  12  ERNTRL=0.0
  13  CONTINUE
      ERNBLK=ERNBLK+ERNTRL
      ERNTOT=ERNTOT+ERNTRL
      TYPE 5
      TYPE*,'Money earned on this TRIAL:',ERNTRL
      TYPE 5
      TYPE*,'Total amount earned on this BLOCK:',ERNBLK
```

```
      TYPE 5
      GO TO 50
C
 20   ERNTRL=ITON*TONALN
      ERNTOT=ERNTOT+ERNTRL
      ERNBLK=ERNBLK+ERNTRL
      TYPE 5
      TYPE*,'Money earned on this TRIAL:' ,ERNTRL
      TYPE 5
      TYPE*,'Total amount earned on this BLOCK:' ,ERNBLK
      TYPE*,' '
      TYPE 5
      GO TO 50
C
 30   IF(NREC.NE.3)GO TO 33
      ERNCVC=CVCDL1
      GO TO 35
 33   ERNCVC=0.0
 35   CONTINUE
      ERNTON=ITON*TONDL1
      ERNBLK=ERNBLK+ERNCVC+ERNTON
      ERNTOT=ERNTOT+ERNCVC+ERNTON
      TRLPTS=ERNCVC+ERNTON
      TYPE 5
      TYPE*,'Money earned on this TRIAL:' ,TRLPTS
      TYPE*,''
      TYPE*,'           For CVCVC MEMORY:',ERNCVC
      TYPE*,'           For         TONE:',ERNTON
      TYPE 5
      TYPE*,''
      TYPE 5
      GO TO 50
C
 40   IF(NREC.NE.3)GO TO 43
      ERNCVC=CVCDL2
      GO TO 45
 43   ERNCVC=0.0
 45   CONTINUE
      ERNTON=ITON*TONDL2
      ERNBLK=ERNBLK+ERNCVC+ERNTON
      ERNTOT=ERNTOT+ERNCVC+ERNTON
      TRLPTS=ERNCVC+ERNTON
      TYPE 5
      TYPE*,'MONEY EARNED ON THIS TRIAL:',TRLPTS
      TYPE*,''
      TYPE*,'           For CVCVC MEMORY:',ERNCVC
      TYPE*,'           For         TONE:',ERNTON
      TYPE 5
      TYPE*,''
      TYPE 5
C
 50   RETURN
```

```
      END

          SUBROUTINE H2TBOX(IBOX)
C
C THIS SUBROUTINE IS USED FOR THE DISPLAYING THE BOX
C FOR THE TONALN ROUTINE IN HEARD2.
C
      COMMON/SCREEN/ICLR(2),IMOV1(4),IMOV2(4),NEWLN(7)
      DIMENSION IBOX(3,5),IMOV3(2)
      LOGICAL*1 ICLR,IMOV1,IMOV2,IMOV3,NEWLN,IBOX
      DATA IMOV3/16,16/
      COMMON /PARAM/NSTIM,NPERTRL,NLET
C
C
      II=MTOUT(1,IMOV2,4)
C
      DO 10 I=1,3
       DO 5 J=1,5
        II=MTOUT(1,IBOX(I,J),1)
 5     CONTINUE
       II=MTOUT(1,NEWLN,7)
 10   CONTINUE
C
      II=MTOUT(1,IMOV3,2)
C
      RETURN
      END
C
C
C
C
          PROGRAM HEARD3
C       PROGRAM FOR THE EXPERIMENTAL CONTROL DAY
C       H3TONE - IS FOR TONE-ALONE TASK.
C
      DIMENSION FNAME(11),FNAME2(11),INFO(12),ISET(4)
      BYTE FNAME,FNAME2
      LOGICAL INFO
      DATA FNAME/'S','N','N','H','3','R','.','D','
     A','T',"0/
      DATA FNAME2/'S','N','N','H','3','S','.','D',
     'A','T',"0/
C
C SET CLOCK OSCILLATING IN MILLISECONDS
C
      CALL CLOCKB(4,-1,,IND)
C
C GATHER A WHOLE BUNCH OF INFORMATION REGARDING THE RUN
C
      TYPE *,''
      TYPE*,'        WELCOME TO HEARD3'
```

```
      TYPE *,' '
C
C SUBJECT NUMBER IS ACCEPTED AS TWO SINGLE-ELEMENT PIECES OF
C   CHARACTER DATA SO THEY CAN BE PLUGGED INTO THE OUTPUT
C   FILENAME.
C
 10   TYPE*,'ENTER SUBJECT NUMBER AS A 2-DIGIT NUMBER'
      ACCEPT 15,ISUB1,ISUB2
 15   FORMAT(2A1)
      TYPE*,'   '
 20   TYPE 25,ISUB1,ISUB2
 25   FORMAT(' CONFIRM THAT THIS IS SUBJECT NUMBER:',2A1)
      TYPE*,'   '
      TYPE*,'                              1=YES'
      TYPE*,'                              0=NO'
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0) GO TO 20
      IF(IANS.NE.1) GO TO 10
C
C OPEN THE FILES
C
      FNAME(2)=ISUB1
      FNAME(3)=ISUB2
      OPEN(UNIT=8,NAME=FNAME,TYPE='NEW')
      FNAME2(2)=ISUB1
      FNAME2(3)=ISUB2
      OPEN(UNIT=9,NAME=FNAME2,TYPE='NEW')
C
C ACCEPT SUBJECT ORDER (FROM 1-2)
C
 30   TYPE*,'ENTER ORDER FOR THIS SUBJECT'
      TYPE*,'   '
      TYPE*,'               1 = PURE - MIXED'
      TYPE*,'               2 = MIXED - PURE'
      ACCEPT 35,IORD
 35   FORMAT(A1)
      IF(IORD.NE.'1'.AND.IORD.NE.'2')GO TO 30
 40   TYPE*,'   '
      TYPE 45,IORD
 45   FORMAT(' IS THE CORRECT ORDER ',A1,'?')
      TYPE*,'   '
      TYPE*,'       1=YES'
      TYPE*,'       0=NO'
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0) GO TO 40
      IF(IANS.NE.1) GO TO 30
C
C CONDITION # IS DETERMINED
C
 50   TYPE*,'WHICH CONDITION IS NEXT?'
      TYPE*,'   '
      TYPE*,'       1 = PURE'
```

```
      TYPE*,'       2 = MIXED'
      TYPE*,'       0 = NO CONDITION - STOP HERE'
      ACCEPT 35,ICOND
 60   TYPE*,'  '
      TYPE 65,ICOND
 65   FORMAT(' CONFIRM THAT YOU WANT CONDITION ',A1)
      TYPE*,'  '
      TYPE*,'      1=YES'
      TYPE*,'      0=NO'
      TYPE*,'  '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 60
      IF(IANS.NE.1) GO TO 50
      IF(ICOND.EQ.'0')GO TO 1000
C
C BLOCK NUMBER.
C
      TYPE*,'THERE ARE 6 BLOCKS IN THIS EXPERIMENT'
      TYPE*,'BLK1=PURE    TRIALS   1 TO  24'
      TYPE*,'BLK2=PURE    TRIALS  25 TO  48'
      TYPE*,'BLK3=MIXED1  TRIALS  49 TO  72'
      TYPE*,'BLK4=MIXED1  TRIALS  73 TO  96'
      TYPE*,'BLK5=MIXED2  TRIALS  97 TO 120'
      TYPE*,'BLK6=MIXED2  TRIALS 121 TO 144'
C
C
 69   TYPE*,'ENTER BLOCK NUMBER (1 TO 6)'
      ACCEPT 35,IBLK
      TYPE 70,IBLK
 70   FORMAT(' CONFIRM THAT YOU WANT BLOCK ',A1)
      TYPE*,'     1=YES'
      TYPE*,'     2=NO '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 69
      IF(IANS.NE.1)GO TO 69
C
C
C DETERMINE # OF TRIALS FOR THE PRESENT BLOCK
C
      NTRIALS=24
 80   TYPE*,'  '
      TYPE*,'YOU WANT TO RUN',NTRIALS,' TRIALS FOR
     .  THIS BLOCK?'
      TYPE*,'  '
      TYPE*,'        1=YES'
      TYPE*,'        0=NO'
      TYPE*,'  '
      ACCEPT*,IANS
      IF(IANS.NE.1.AND.IANS.NE.0)GO TO 80
      IF(IANS.NE.1)TYPE*,'HOW MANY TRIALS FOR THIS BLOCK'
      IF(IANS.NE.1)ACCEPT*,NTRIALS
C
```

```
 85   TYPE*,'WHICH EAR IS THE CORD ON?'
      TYPE*,'  '
      TYPE*,'       0=LEFT EAR'
      TYPE*,'       1=RIGHT EAR'
      TYPE*,'  '
      ACCEPT 84,IEAR
 84   FORMAT(I1)
      IF(IEAR.NE.1.AND.IEAR.NE.0)GO TO 85
      TYPE*,'THIS BLOCK IS SET WITH EAR',IEAR
      IF(IEAR.EQ.1)IAEAR='1'
      IF(IEAR.EQ.0)IAEAR='0'
C
C
 86   TYPE*,'WHICH SET OF TRIALS FOR THIS CONDITION?'
      TYPE*,'      '
      TYPE*,'   1=SET 1  (01 TO 24)'
      TYPE*,'   2=SET 2  (25 TO 48)'
      TYPE*,'   3=SET 3  (49 TO 72)'
      TYPE*,'   4=SET 4  (73 TO 96)'
      TYPE*,'   5=SET 5  (97 TO 120)'
      TYPE*,'   6=SET 6  (121 TO 144)'
      TYPE*,'   7=PRACTICE '
      TYPE*,'          '
      ACCEPT*,ITSET
      IF(ITSET .LT.1 .OR. ITSET .GT.7)GO TO 86
      TYPE*,'THIS IS SET',ITSET
C
C
C SET VALUES OF INFO (TO BE PASSED)
C
      INFO(1)='S'
      INFO(2)=ISUB1
      INFO(3)=ISUB2
      INFO(4)='O'
      INFO(5)=IORD
      INFO(6)='C'
      INFO(7)=ICOND
      INFO(8)='B'
      INFO(9)=IBLK
      INFO(10)='E'
      INFO(11)=IAEAR
C
C ZERO VARIABLES FOR PERCENT CORRECT.
C
      HITLM=0.0
      HITRM=0.0
      HITLP=0.0
      HITRP=0.0
      MISSLM=0.0
      MISSRM=0.0
      MISSLP=0.0
      MISSRP=0.0
```

```
          CRLMNM=0.0
          CRRMNM=0.0
          CRLMM=0.0
          CRRMM=0.0
          CRLP=0.0
          CRRP=0.0
          FALMNM=0.0
          FARMNM=0.0
          FALMM=0.0
          FARMM=0.0
          FALP=0.0
          FARP=0.0
          PCORLP=0.0
          PCORRP=0.0
          PCORLM=0.0
          PCORRM=0.0
C
          DO 120 ITRL=1,NTRIALS
  100      CALL H3TONE(INFO,ITRL,IEAR,ITSET,HITLM,HITRM,
      1            HITLP,HITRP,MISSLM,MISSRM,MISSLP,MISSRP,
                   CRLMNM,
      2            CRRMNM,CRLMM,CRRMM,CRLP,CRRP,FALMNM,FARMNM,
                   FALMM,
      3            FARMM,FALP,FARP)
C
  120     CONTINUE
C
C
          IF(ITSET.EQ.7)GO TO 200
          IF(ITSET.NE.1.AND.ITSET.NE.2)GO TO 190
          IF(IEAR.EQ.1)GO TO 130
          PCORLP=(HITLP+CRLP)/24*100
          WRITE(9,125)HITLP,MISSLP,CRLP,FALP,PCORLP
  125     FORMAT(2X,'LEFT EAR - PURE CONDITION',/,2X,'
                   HIT',5X,'MISS',
      1            5X,'C.R.',6X,'FA',7X,'PCORLP',/,2X,F4
                   .1,4X,I4,5X,
      2            F4.1,5X,F4.1,5X,F5.2)
C
          GO TO 200
C
C
C
  130     PCORRP=(HITRP+CRRP)/24*100
          WRITE(9,126)HITRP,MISSRP,CRRP,FARP,PCORRP
  126     FORMAT(2X,'RIGHT EAR-PURE CONDITION',/,2X,'H
                   IT',5X,'MISS',
      1            5X,'C.R.',6X,'FA',7X,'PCORRP',/,2X,F4.1,
                   4X,I4,5X,
      2            F4.1,5X,F4.1,5X,F5.2)
C
          GO TO 200
```

```
C
C
C
C MIXED CONDITION PRINT OUTS:
C
 190    IF(IEAR.EQ.1)GO TO 195
        PCORLM=(HITLM+CRLMNM+CRLMM)/24*100
        WRITE(9,144)HITLM,MISSLM,CRLMNM,CRLMM,FALMNM,
                    FALMM,PCORLM
 144    FORMAT(2X,'LEFT EAR - MIXED CONDITION',/,2X,
              'HIT',5X,
     1        'MISS',5X,'CRLMNM',5X,'CRLMM',5X,'FAL
              MNM',5X,'FALMM',
     2        5X,'PCORLM',/,2X,F4.1,
     3        4X,I4,5X,F4.1,7X,F4.1,7X,F4.1,6X,F4.1
              ,5X,F5.2)
C
        GO TO 200
C
C
 195    PCORRM=(HITRM+CRRMNM+CRRMM)/24*100
        WRITE(9,145)HITRM,MISSRM,CRRMNM,CRRMM,FARMNM
        ,FARMM,PCORRM
 145    FORMAT(2X,'RIGHT EAR- MIXED CONDITION',/,2X,
              'HIT',5X,
     1        'MISS',5X,'CRRMNM',5X,'CRRMM',5X,'FARMNM'
              ,5X,'FARMM',
     2        5X,'PCORRM',/,2X,F4.1,
     3        4X,I4,5X,F4.1,7X,F4.1,7X,F4.1,6X,F4.1,
              5X,F5.2)
C
        GO TO 200
C
C
C
C
C PROGRAM CONTROL IS NOW SENT BACK UP TO WHERE CONDITION
C # IS
C   DETERMINED TO SEE IF ANOTHER CONDITION SHOULD BE RUN
C
 200    GO TO 50
C
C
C MAKE SURE THAT THE E HASN'T BOO-BOO-ED OR CHANGED HIS/HER MIND
C
 1000   TYPE*,'   '
        TYPE*,'ARE YOU SURE YOU WANT TO STOP?'
        TYPE*,'   '
        TYPE*,'        1=YES'
        TYPE*,'        0=NO'
        TYPE*,'   '
        ACCEPT*,IANS
```

```
        IF(IANS.NE.1.AND.IANS.NE.0)GO TO 1000
        IF(IANS.EQ.0) GO TO 50
C
C WRITE A SENTINAL
C
        WRITE(8,135)
 135    FORMAT('999999999999999',60X)
C
        CALL CLOSE(8)
C
C SET RECORDER TO AN UNPAUSE STATE.
C
        CALL DOUT(0,"20000,IERR,"0)
C
        STOP
        END
C
C
                SUBROUTINE H3TONE(INFO,ITRL,IEAR,ITSET,
                                  HITLM,HITRM,
     1           HITLP,HITRP,MISSLM,MISSRM,MISSLP,MISSRP,
                 CRLMNM,
     2           CRRMNM,CRLMM,CRRMM,CRLP,CRRP,FALMNM,
                 FARMNM,FALMM,
     3           FARMM,FALP,FARP)
C
        DIMENSION INFO(12),ICOR(144)
        LOGICAL INFO
        DATA ICOR/0,1,0,0,1,1,0,0,1,0,1,1,0,0,1,1,0,
                  0,1,1,1,0,1,0,
     1            0,1,0,0,1,1,0,0,1,0,1,1,0,0,1,1,0,
                  0,1,1,1,0,1,0,
     2            1,1,0,2,1,0,1,2,1,0,1,2,0,1,1,2,1,
                  0,1,2,1,0,1,2,
     3            1,1,0,2,1,0,1,2,1,0,1,2,0,1,1,2,1,
                  0,1,2,1,0,1,2,
     4            1,1,2,1,0,0,1,2,1,0,2,1,2,1,1,2,0,
                  0,1,1,1,0,1,2,
     5            1,1,2,1,0,0,1,2,1,0,2,1,2,1,1,2,0,
                  0,1,1,1,0,1,2/
C
C
        IF(ITSET.EQ.1)ISET=0
        IF(ITSET.EQ.2)ISET=24
        IF(ITSET.EQ.3)ISET=48
        IF(ITSET.EQ.4)ISET=72
        IF(ITSET.EQ.5)ISET=96
        IF(ITSET.EQ.6)ISET=120
        IF(ITSET.EQ.7)ISET=7
        ITRL=(ITRL+ISET)
        TYPE*,'TRIAL NUMBER',ITRL
C
```

```
            PAUSE 'PUSH RETURN TO START TRIAL'
C
C START RECORDER
C
            CALL CLOCKB(,,,IND)
 5          CALL DOUT(0,"20000,IERR,"0)
            IF(ICLOKB().LT.20)GO TO 5
 6          CALL DOUT(0,"20000,IERR,"20000)
            IF(ICLOKB().LT.40)GO TO 6
C
 9          IF (ICLOKB().LE.500)GO TO 9
C
C WAIT FOR WARNING TONE
C
  10        IF(IDINP(0,"100000,IERR,INPUT).EQ.0) GO TO 10
            TYPE*,' WARNING TONE'
C
C
C ZERO CLOCK AND WAIT 1000 MSECS
C
            CALL CLOCKB(,,,IND)
 20         IF(ICLOKB().LE.1000) GO TO 20
C
C DETECT BOTH TONE PAIRS
C
 40         IF(IDINP(0,"100000,IERR,INPUT).EQ.0) GO TO 40
 50         IF(IDINP(0,"100000,IERR,INPUT).NE.0) GO TO 50
            TYPE*,' TONE 1 OFFSET'
C
 60         IF(IDINP(0,"100000,IERR,INPUT).EQ.0) GO TO 60
 70         IF(IDINP(0,"100000,IERR,INPUT).NE.0) GO TO 70
            TYPE*,' TONE 2 OFFSET'
C
C STOP RECORDER
C
            CALL CLOCKB(,,,IND)
  71        CALL DOUT(0,"20000,IERR,"0)
            IF(ICLOKB().LT.20)GO TO 71
  72        CALL DOUT(0,"20000,IERR,"20000)
            IF(ICLOKB().LT.40)GO TO 72
C
C WAIT FOR MUSIC RESPONSE
C
            CALL DOUT(0,"100000,IERR,"0)
            CALL DOUT(0,"100000,IERR,"100000)
  80        IF(IDINP(0,"17,IERR,INPUT).EQ.0) GO TO 80
C
C
C SCORE RESPONSE
C
            IF(INPUT.EQ.2.OR.INPUT.EQ.4) IRESP=1      YES
            IF(INPUT.EQ.1.OR.INPUT.EQ.8) IRESP=0      NO
```

```
C
C TO SKIP SCORING IF IS PRACTICE TRIAL (ITSET=7)
      IF(ITSET.EQ.7)GO TO 200
C
C NOW TO MATCH THE RESPONSE (YES=0/NO=1) TO DATA ARRAY
C ICOR AND IEAR TO GET SCORE.
C-----------------------------------------------------
C
C NOTE: THE KEY IS AS FOLLOWS:
C
C      ITRLR=00 HIT  - LEFT EAR PURE COND
C      ITRLR=01 HIT  - LEFT EAR MIX COND
C      ITRLR=02 MISS - LEFT EAR PURE COND
C      ITRLR=03 MISS - LEFT EAR MIX COND
C      ITRLR=04 C.R. - LEFT EAR PURE
C      ITRLR=05 C.R. - LEFT EAR MIX - NON-MATCHING NO
C      ITRLR=06 C.R. - LEFT EAR MIX - MATCHING NO
C      ITRLR=07 F.A. - LEFT EAR PURE COND
C      ITRLR=08 F.A. - LEFT EAR MIX - NON-MATCHING NO
C      ITRLR=09 F.A. - LEFT EAR MIX - MATCHING NO
C      ITRLR=10 HIT - RIGHT EAR PURE COND
C      ITRLR=11 HIT - RIGHT EAR MIX COND
C      ITRLR=12 MISS- RIGHT EAR PURE COND
C      ITRLR=13 MISS- RIGHT EAR MIX COND
C      ITRLR=14 C.R.- RIGHT EAR PURE COND
C      ITRLR=15 C.R.- RIGHT EAR MIX - NON-MATCHING NO
C      ITRLR=16 C.R.- RIGHT EAR MIX - MATCHING NO
C      ITRLR=17 F.A.- RIGHT EAR PURE COND
C      ITRLR=18 F.A.- RIGHT EAR MIX - NON-MATCHING NO
C      ITRLR=19 F.A.- RIGHT EAR MIX - MATCHING NO
C
C--------------------------------------------------------
C
C SET ITRLR TO A VALUE OF 25
      ITRLR=25
C
C (1) FIRST THE YES RESPONSES GIVING ONE OF 4 HITS:
C
      IF(IRESP .EQ. 0)GO TO 100
      IF(ITSET.EQ.1.OR.ITSET.EQ.2)GO TO 99
      IF(IRESP .EQ. ICOR(ITRL).AND.IEAR.EQ.0)ITRLR=1
      IF(IRESP .EQ. ICOR(ITRL).AND.IEAR.EQ.1)ITRLR=11
      IF(IRESP.EQ.ICOR(ITRL).AND.IEAR.EQ.0)HITLM=HITLM+1
      IF(IRESP.EQ.ICOR(ITRL).AND.IEAR.EQ.1)HITRM=HITRM+1
      GO TO 104
 99   IF(IRESP.EQ.ICOR(ITRL).AND.IEAR.EQ.0)ITRLR=0
      IF(IRESP.EQ.ICOR(ITRL).AND.IEAR.EQ.1)ITRLR=10
      IF(IRESP.EQ.ICOR(ITRL).AND.IEAR.EQ.0)HITLP=HITLP+1
      IF(IRESP.EQ.ICOR(ITRL).AND.IEAR.EQ.1)HITRP=HITRP+1
      GO TO 104
C
C
```

```
C
C FOR THE "NO" RESPONSES HAVE CR'S OR MISSES:
C
C TO DETERMINE IF MISS:
 100      IF(ICOR(ITRL).EQ.0.OR.ICOR(ITRL).EQ.2)GO TO 101
          IF(ITSET.EQ.1.OR.ITSET.EQ.2)GO TO 81
           IF(ICOR(ITRL).EQ.1.AND.IEAR.EQ.0)ITRLR=3
           IF(ICOR(ITRL).EQ.1.AND.IEAR.EQ.1)ITRLR=13
            IF(ITRLR.EQ.3)MISSLM=MISSLM+1
            IF(ITRLR.EQ.13)MISSRM=MISSRM+1
          GO TO 110
  81     IF(ICOR(ITRL).EQ.1.AND.IEAR.EQ.0)ITRLR=2
          IF(ICOR(ITRL).EQ.1.AND.IEAR.EQ.1)ITRLR=12
           IF(ITRLR.EQ.2)MISSLP=MISSLP+1
           IF(ITRLR.EQ.12)MISSRP=MISSRP+1
          GO TO 110
C
C
C
C TO DETERMINE IF WAS A  CORRECT REJECTION.
C
  101     CONTINUE
          IF(ITSET.EQ.1.OR.ITSET.EQ.2)GO TO 112
          IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.0)ITRLR=5
          IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.1)ITRLR=15
           IF(ITRLR.EQ.5)CRLMNM=CRLMNM+1
           IF(ITRLR.EQ.15)CRRMNM=CRRMNM+1
          IF(ICOR(ITRL).EQ.2.AND.IEAR.EQ.0)ITRLR=6
          IF(ICOR(ITRL).EQ.2.AND.IEAR.EQ.1)ITRLR=16
           IF(ITRLR.EQ.6)CRLMM=CRLMM+1
           IF(ITRLR.EQ.16)CRRMM=CRRMM+1
          GO TO 110
C
 112      IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.0)ITRLR=4
          IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.1)ITRLR=14
           IF(ITRLR.EQ.4)CRLP=CRLP+1
           IF(ITRLR.EQ.14)CRRP=CRRP+1
C
C
C
C TO DETERMINE IF WAS A FALSE ALARM.
C
 104      IF(ITRLR.NE.25)GO TO 110
C
          IF(ITSET.EQ.1.OR.ITSET.EQ.2)GO TO 105
C
          IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.0)ITRLR=8
          IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.1)ITRLR=18
          IF(ICOR(ITRL).EQ.2.AND.IEAR.EQ.0)ITRLR=9
          IF(ICOR(ITRL).EQ.2.AND.IEAR.EQ.1)ITRLR=19
           IF(ITRLR.EQ.8)FALMNM=FALMNM+1
           IF(ITRLR.EQ.18)FARMNM=FARMNM+1
```

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        IF(ITRLR.EQ.9)FALMM=FALMM+1
        IF(ITRLR.EQ.19)FARMM=FARMM+1
C
 105   IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.0)ITRLR=7
       IF(ICOR(ITRL).EQ.0.AND.IEAR.EQ.1)ITRLR=17
        IF(ITRLR.EQ.7)FALP=FALP+1
        IF(ITRLR.EQ.17)FARP=FARP+1
C
 110   CONTINUE
C
C TO WRITE THE RESPONSE TO THE FILE:
C
       WRITE(8,90)(INFO(J),J=1,11),ITRL,IRESP,ITRLR
 90    FORMAT(11A1,3X,'T',I3,3X,'RESP',I2,3X,'SCORE',I2)
C
C
 200   CONTINUE
C
C
C
       ITRL=(ITRL-ISET)
       RETURN
       END
```