A STRINGENT TEST OF SANDERS' FOUR-STAGE, COGNITIVE-ENERGETICAL MODEL OF STRESS AND PERFORMANCE

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CHAPTER I

INTRODUCTION

A continuing debate in the literature involves two different theories of information processing - discrete stage models and continuous flow models. Although history is on the side of the discrete stage models, popularity seems to have swung toward the continuous flow models in recent years. Miller (1988) examines this debate and suggests that perhaps it is not a particularly meaningful one. He reasons that it may be an oversimplification to categorize all information processing models into two mutually exclusive groups. Rather, he suggests that it might be more accurate to conceptualize information processing models on a continuum, which range from discrete models at one end to continuous models at the other.

In this debate, the existence of stages or levels of processing is not questioned. Indeed, proponents of both discrete stage models and continuous flow models assert that there are different levels of operations that take place on internal information codes (Sanders, 1990). It may be that each information processing model contains some stages which are discrete and others which are continuous, or that each model may be discrete in some aspects while continuous in others.

Miller (1988) identifies three different ways in which a particular stage or model can be continuous or discrete - representation, transformation, and transmission. Representation refers to the type of input information a stage receives. Transformation has to do with the processes that take place during a stage to produce a particular output. Transmission deals with the way a stage makes its output available to the next stage and also the relationship between stages (do they operate one at a time or simultaneously). A fourth manner in which a stage may be discrete or continuous has been recently identified by Miller (1990). He postulates that there may be variation in the a priori state of a person which actually changes the operation of a particular stage between uses of that stage. In light of these four aspects even one stage within a model can be conceptualized as relatively discrete in some aspects or relatively continuous in others. Models may also be described as discrete in some ways and continuous in others. Thus, stages and models may be seen as falling somewhere on a continuum from discrete to continuous. This current trend of thinking about models of information processing does indeed suggest that labeling a particular model as discrete or continuous may be neither useful nor accurate.

On one end of this continuum are the discrete stage models of human information processing which date back to the 1800's. In general, proponents of these models assert that humans process information through a series of discrete stages that operate in a linear fashion. The assumption inherent in these models is that information transmission is discrete, such that one stage is completed before the next one begins.

Donders (1868) put forth a model of processing which used subtraction to attempt to estimate the time taken by a particular stage. The idea behind the subtraction method was that the time required to process stage "X" could be calculated by taking a task with n stages and subtracting a task with n-1 stages (where the missing stage was stage X). One criticism of this subtraction method is that it is doubtful that the various stages which are supposed to be cancelling each other out, are actually identical (Meyer, Osman, Irwin, and Yantis, 1988).

Despite this criticism, the idea of linear stages in information processing did not die and indeed went through a boom in the seventies as a result of a new method developed by Sternberg (1969) based on additive factor logic. Sternberg anchored his additive factor method on the inference that if separate independent variables are additive in their effects on reaction time (i.e., significant main effects only for each variable), then it can be assumed that they are affecting different processing stages. Conversely, if interactions are seen in the effects of the variables on reaction time, then it can be assumed that the variables are not discrete and have at least one stage in common. Sternberg's additive factor method is the basis of many of the current discrete stage models of information processing.

Continuous flow models of information processing represent the other end of the continuum. They involve the idea that there are levels or subprocesses through which information passes. These models suggest that information builds up continuously, and may be passed on continuously from one subprocess to the next. Hence both transformation and transmission are considered to be continuous. Information accumulates until a particular level of activation is reached and then a response is executed. Unlike the discrete processing models where one stage must be completed before another begins, continuous flow models involve parallel processing (i.e., more than one subprocess may be operating at any given time). Physiological evidence is often offered in support of continuous flow models (Miller, 1988). It is assumed that information must flow continuously since it appears that individual neurons fire continuously at different rates and at different times.

Although this physiological evidence may provide support for continuity of the representational and transformational aspects of information processing, transmission is usually seen as operating as the result of a particular threshold being reached. This would suggest that the process behind transmission appears to be discrete. Sanders (1990) disputes the use of physiological evidence in the assessment of information processing models, pointing out that physiological processes are not necessarily comparable to the processes involved in choice reaction time.

One of the best known proponents of the discrete stage models is Sanders, who developed a four stage cognitive-energetical model of information processing (Sanders, 1983). He postulates four discrete stages of processing, as well as specific variables which affect each stage. The four stages of processing in this model are stimulus preprocessing, feature extraction, response choice, and motor adjustment. Stimulus preprocessing is a stage which involves taking in a stimulus and developing a representation of it. The variable of stimulus intensity, the contrast between a signal and its background, affects this stage.

The second stage, feature extraction, is one in which the stimulus that has been taken in is identified, in terms of its features or components. This stage is affected by the variable of stimulus quality which is typically manipulated by superimposing visual noise over the stimulus. One common method of manipulating stimulus quality is degrading the stimulus with a checkerboard masking pattern (Sternberg, 1969). Another method of stimulus degradation is superimposing a random dot mask on the stimulus (e.g. Logsdon, Hochhaus, Williams, Rundell, and Maxwell, 1984). Sanders' third stage, response choice, provides a link between perception and action by selecting the particular motor program to be carried out. The variable of stimulus-response compatibility affects this stage. Sanders (1980, p. 339) says that S-R compatibility "refers to the degree of natural or overlearned relations between signals and responses." A number of tasks have been designed to measure the effects of S-R compatibility on reaction time. Naming familiar verbal materials is a task considered high in S-R compatibility, as well as pressing a response button with a tactually stimulated finger.

Finally, the fourth stage in Sanders' model is motor adjustment, which involves the actual motor readiness required to make a response. After reviewing the literature involving the variable of time uncertainty - whether participants can anticipate when a response will be demanded - Sanders (1980) concluded that this variable affects the motor adjustment stage. The manipulation of time uncertainty involves varying the foreperiod duration between the presentation of a warning signal and the stimulus.

Much research has been done that supports the four variables which Sanders (1983) proposed. These studies suggest that the four variables do have effects on reaction time and thus also affect information processing. The most common methodology for testing Sanders' model involves including two of these variables at a time in one study. If they have additive, non-interacting effects on reaction time it can be concluded that they are affecting two distinct, separate stages. (See Reaction Time Research section in Chapter II for a review of these studies.) Everett, Hochhaus, and Brown (1985) included three of Sanders' suggested variables in their study - stimulus intensity, stimulus quality, and stimulus-response compatibility. Their findings suggest that these three variables are non-interacting and therefore yield support for the existence of three of Sanders' four independent processing stages. However, the greatest challenge to the model would be to include all four of the suggested variables in a single research effort. The results would strongly support Sanders' theory if all four variables were found to have additive, non-interacting effects on reaction time. To date, this has not been accomplished.

CHAPTER II

LITERATURE REVIEW

Historical Approaches to the Study of Information Processing

Meyer, Osman, Irwin, and Yantis (1988) suggest that one of the earliest contributers to the scientific study of human information processing was work reported by Bessel in 1823. Bessel was an astronomer who developed the "personal equation" which was a measure of the difference between two peoples' time estimates of when an astronomical event occurred. This suggested that there may be mental processes which take place and may require different amounts of time for different people.

In 1850, Hermann von Helmholtz pioneered the use of reaction-time procedures for neurophysiological study. He used this procedure to determine the rate of neural conduction. Meyer et al. suggest that following this initial work with reaction time, the next fifty years saw a surge of research which branched in two different directions. Some of the researchers continued to focus on developing the technique of reaction time measurement while others began to consider accuracy measurements as well.

Donders (1868/1969) took a leading role in further developing reaction time research. His work made it possible to begin thinking in terms of stages of information processing. Donders developed his subtraction method using three different types of reaction time tasks which he labeled Task A, Task B, and Task C. Task A (which is now often referred to as simple reaction time) was a task in which there was only one stimulus presented and one possible response to the stimulus. Task B (currently known as a choice reaction time task or disjoint reaction time) involved the presentation of several stimuli with several possible response choices. Task C (go/no go reaction time) involved presenting a variety of stimuli but with instructions to respond to only one stimulus while withholding responses to the remainder.

Donders believed that subtraction of the reaction time for Task A (which involved no stimulus discrimination or response choice) from the reaction time for Task B (which did require those processes), would yield a remaining time which would represent the time which was needed to carry out stimulus discrimination and response choice. Further, he reasoned that by subtracting reaction time for Task C (which required only stimulus discrimination) from Task B, the resulting reaction time would be that needed to carry out the process of response choice. Finally he subtracted the reaction time for Task A from the reaction time for Task C to find the reaction time involved in the process of stimulus discrimination. Thus using Donders' subtraction method, it appeared that it was possible to measure simple reaction time, stimulus discrimination and response choice.

Two assumptions were necessary for the subtraction method. One was that reaction times for different mental processes combine in an additive manner to yield an overall reaction time. The second assumption was one that Kulpe called the "assumption of pure insertion" (Sanders, 1980). This assumption is that a switch could be made from one type of reaction time procedure to another, simply inserting or deleting stages of processing, without in any way affecting the remaining stages.

Meyer et al. (1988) report that many researchers were excited by the possibility of identifying stages of mental processing and began applying it in their own work. One of these scientists was Wilhelm Wundt who added a fourth task, D-reaction. This task involved making a single response to multiple stimuli as soon as the stimuli were identified correctly. Wundt went on to measure a wide variety of different processes including reflexes, perception, and judgement.

Meyer et al. (1988) identify an end to the initial boom period of reaction time research resulting from the discovery that this research produced inconsistent results, probably due to a violation of the pure insertion assumption. It was one of Wundt's students, Oswald Kulpe, who was alarmed by the fact that different estimates of the duration of a particular stage were found in various laberatories. Kulpe published a critique of the subtraction method. With the discovery of the inconsistent results, it became apparent that the assumptions made by the subtraction method may not be valid. As Pachella (1974) points out, the two tasks used in the subtraction method may be fundamentally different, beyond just the insertion or deletion of one processing stage, thereby accounting for inconsistent results. Very little research was continued along these lines at this point, and that which was done was given very little recognition for some time (Meyer et al., 1988).

A major force in the renewed interest in reaction time research was Sternberg's (1969) theory using his additive factor method. The assumption inherent in Sternberg's theory is that there are several stages of information processing which are successive and do not overlap. Sternberg defines a stage as "one of a series of successive processes that operates on an input to produce an output, and contributes an additive component to the RT" (Sternberg, 1969, p. 282). These stages can be discovered by observing the effects of various factors on mean reaction time. If these factors influence different stages, their reaction times will be additive so that total reaction time is the sum of the reaction times for the different stages. If all two-way interactions are zero, then that experiment using "X" number of factors distinguishes "X" number of stages. If two or more factors are interactive in their effects on reaction time, then it is assumed that they influence at least one stage in common.

Sternberg (1969) believes that it is useful to observe the patterns of interaction among factors to learn about the operations performed by a particular stage and its position in a series of stages. However, it should be noted that while Sternberg's model would predict a particular series of stages from a given body of data, equally valid models would produce alternative explanations given the same data. Sternberg points out that one is not able to determine the total duration of time for a stage using the additive factor method, which is what Donders had hoped to accomplish. However, one is able to learn "whether there is such a stage, what influences it, what it accomplishes, and what its relation is to other stages" (Sternberg, 1969, p. 295).

The additive factor method, as Pachella (1974) indicates, has not gone without criticism. One of the criticisms is similar to that of the subtraction method.

Manipulating various factor levels may cause a larger change in the overall processing sequence, so it may not be logical to assume that changes in reaction time are simply due to the manipulation of the factors. Also, Sternberg (1969) states that it is possible that two factors may influence a similar stage and still be additive in their effect instead of interactive. Despite these potential problems with choice reaction time studies using the additive factor logic, they do seem to produce fairly consistent results which lend support to the method. Pachella (1974) suggests that cognitive psychology seems to be characterized by the study of events that cannot be observed directly. Information processing stages cannot be directly observed, so reaction time research is used as the best available alternate method of gathering information about these stages.

Current Trends In The Discrete - Continuous Debate

Because reaction time research has proven to be quite promising in gaining information about human information processing, and there appeared to be some room for improvement on the additive factor method, some researchers have put forth attempts at developing alternative models. One major benefit of using a variety of information processing models in research is that if similar results are obtained regarding stages of information processing, then these results will be more convincing. One example of an alternative model is the comparative-influence method developed by Salthouse (1981), which combined Donders' subtraction method and Sternberg's additive factor method. The comparative-influence method compares a choice reaction time task with a tachistoscopic task. The reaction time task is assumed to contain all of the stages involved in the tachistoscopic task plus at least one additional stage. The method is important since it allows the incorporation of the body of literature on reaction time tasks and tachistoscopic tasks. Results from many of Salthouse's experiments using his method are consistent with results obtained using the additive factor method. Since similar stages of information processing have been obtained using these two different methodologies, the likelihood of the existence of these separate stages is enhanced.

Some theorists have gone in different directions with their models of mental processes. Continuous flow models provide alternative explanations to information processing, which contain both similarities to and differences from discrete stage models. Sanders (1990, p. 124) points out that a basic assumption common to all information processing models is that "human cognitive performance is mediated by way of processing levels or stages, each performing its own set of operations by using available internal codes." An example of a continuous flow model, to be considered here, is that of McClelland's (1979) cascade model. One of the assumptions of this model, like discrete stage models, is that the information processing system is composed of several subprocesses. However, the cascade model, as well as other continuous flow models, assumes that the various subprocesses are active continuously and simultaneously. This means that outputs from one subprocess are constantly available as inputs to another subprocess. One similarity of continuous flow models to discrete stage models is linearity. "Outputs are passed in only one direction through the system of processes, with no skipping or bypassing of subprocesses," (McClelland, 1979, p. 290). Response execution is assumed to be a final, discrete event.

Sanders' Cognitive-energetical Model

Sanders (1983) has also developed an alternative information processing model that he calls a cognitive-energetical model, which relates stress and performance. He conceptualizes stress as an intervening variable between perceived external demands and capabilities to adapt to those demands. His model is designed to overcome the limitations in the two primary models of performance which exist. One of those existing conceptual frameworks is that of linear stage models, such as Sternberg's (1969) model using the additive factor method. Sanders (1983) believes the additive factor method has problems because it is based on several assumptions (cognitive processing is unidimensional, there is strict serial processing between stages, no feedback loops occur during the reaction process, and there is a constant stage output), any of which are easily violated. As McClelland (1979) points out, when these assumptions are not met in research, then the data from the research become subject to multiple interpretations.

The other existing conceptual framework considered by Sanders is that of capacity models, whose supporters are concerned with how resources are allocated to the various processing operations. One drawback of the resource allocation models is the lack of specification of assumptions about structural constraints. Therefore, virtually any experimental results could be taken as support of these models.

Sanders (1977) believes that it is important to consider both functional components (issues like attention, alertness) and structural components (mechanisms for processing information) in formulating a theory on stress and performance. Traditional models have been one-dimensional, focusing only on structural components. Sanders assumes, in formulating his theory, that the total time taken by a processing stage is affected by both the computational demands of the stage and the state of the individual. This allows for the consideration of influences like the impact of drugs on performance, which probably affect both structural and functional factors. Sanders (1980) further recognizes that variables such as signal intensity and foreperiod duration are difficult to handle in a one-dimensional model of information processing because they are variables primarily associated with functional factors such as alertness.

In developing the cognitive-energetical model, Sanders (1983) uses a linear stage model as the starting point. He has repeatedly reviewed a variety of research using choice reaction tasks and additive factor logic and has hypothesized about what processing stages may exist based on the results. Initially, Sanders (1977) concluded that at least three additive stages made up the information processing sequence. They were encoding, response choice, and motor adjustment. In 1980, Sanders delineated his ideas about the concept of a stage, stating that a stage is made up of "a functionally independent set of processes," (Sanders, 1980, p. 336) and that within a stage, these processes may overlap or run in parallel. He suggested that it is not known exactly how many stages exist, but that it is important to develop a theory with a finite set of stages and to learn more about them.

As more research using choice reaction tasks was completed, a growing number of factors were found to have additive effects on reaction time. In 1980, Sanders considered the possibility of six stages, based on additive effects found in the literature (Sanders, 1980). The six stages were: 1) preprocessing - a stage affected by the variable of signal contrast; 2) feature extraction - affected by the factor of signal quality; 3) identification - affected by signal discriminability and word frequency; 4) response choice - affected by S-R compatability; 5) response programming - affected by response specificity; and 6) motor adjustment - affected by instructed muscle tension.

In 1981, Sanders first outlined his cognitive-energetical model, and further elaborated on it in 1983 (Sanders, 1983). He indicated that this model would include the four variables that had been best established by existing evidence, which are: 1) stimulus preprocessing; 2) feature extraction; 3) response choice; and 4) motor adjustment. He further specified that different types of energy resources are needed by each of these stages. The three different energy sources are arousal, activation, and effort. Sanders (1981) conceptualizes arousal as a phasic response to input. Activation is thought to be a tonic readiness to respond. Finally, effort serves to balance out arousal and activation. Effort increases to stimulate activity when arousal and activation are low while effort is used to moderate high levels of arousal and activation.

Sanders (1983) asserts that the stage of stimulus preprocessing does not require a direct energy source since it depends on automatic processes. It is a stage that consists of taking in the stimulus and internally representing it. This stage also has an impact on the energetical mechanism of arousal used by the next stage. The experimental variable of stimulus intensity has been shown to affect the stimulus preprocessing stage.

The stage of feature extraction appears to involve an encoding process in which relevant aspects of a percept are separated from irrelevant aspects. Sanders suggests that this process is one of selective attention which uses the energetical mechanism of arousal, while also being indirectly affected by effort. The variable of stimulus quality has been found to affect this process of signal identification.

The response choice stage appears to involve reasoning processes and is the link between perception and action. Conscious processing is the label suggested to describe the activity at this stage. It is directly affected by the energy source of effort.

Finally, the motor adjustment stage involves general motor readiness to respond. Motor adjustment, Sanders suggests, can be affected by timing and preparatory processes which are similar to alertness. Activation is the energy source directly affecting this stage, while effort has some indirect effects. Time uncertainty is the experimental variable which affects the motor adjustment stage.

Stress is assumed to result when the effort mechanism becomes overloaded or fails to make the necessary adjustments between arousal and activation. Sanders theorizes that there is an overall evaluation mechanism to assess the appropriate functioning of this information processing system. It receives feedback on both the physiological state of the system and the cognitive aspect of adequacy of performance.

Sanders (1983) suggests that his comprehensive model of information processing could be tested with reaction time research including the four variables of stimulus intensity, stimulus quality, stimulus-response compatability, and time uncertainty. If these variables were found to affect reaction time, and to be additive in their effects, then the results would lend support to Sanders' cognitive-energetical model.

Reaction Time Research

A large body of research using reaction time tasks exists in the literature. These studies have incorporated a wide variety of different experimental variables in search of patterns of additivity and interaction among these variables. The following discussion will be limited to a consideration of experiments that have included one or more of the four variables that Sanders (1983) has identified as affecting his four proposed processing stages. These variables are stimulus intensity, stimulus quality, S-R compatablity, and time uncertainty. Several of the studies reviewed below contain more than one of these variables. Although they are discussed in the section on one of the variables, the results of the other variables in the study are important as well.

Stimulus Intensity

Stimulus intensity is the variable thought to affect the preprocessing stage of information processing (Sanders, 1983). The way in which stimulus intensity is varied depends upon the type of stimulus being used. Most experiments tend to use visual stimuli, varying such qualities as the brightness of a flash of light or the contrast of a letter or number presented on a video monitor. Several experiments have also used auditory stimuli, varying the loudness of a tone.

One example of reaction time research using stimulus intensity as one of the variables is found in Raab, Fehrer, and Hershenson (1961). Raab and his associates measured reaction time from the onset of the stimulus, a flash of light, until the participant responded by pressing a telegraph key. Three different luminance values were used to manipulate stimulus intensity. Foreperiod duration was manipulated as well, with three different time periods occurring between a warning tone and the presentation of the light flash. They also varied stimulus duration. The results showed significant, additive effects of stimulus intensity and foreperiod duration, implying that these two variables affect separate processing stages, as Sanders' (1983) model would predict.

Shwartz, Pomerantz, and Egeth (1977, Experiment 1) used stimuli consisting of arrows which pointed downward either to the right or the left. The task of the participant was to press a response button upon the presentation of the stimulus. Stimulus intensity was varied, with the dots making up the arrows being either bright or dim. S-R compatibility was also varied, with the correct response being either to press the button the arrow pointed to (compatible condition) or to press the opposite button (incompatible response). Finally, the variable of stimulus similarity (not one of the four variables included in the model by Sanders, 1983) was manipulated by varying the arrows' angles of departure from the verticle. The effects of the three main effects were found to be significant and additive in their effects on reaction time.

In a study by Bernstein, Chu, Briggs, and Schurman (1973), participants had to fixate on a cross, listen for a warning signal, and respond with a telegraphic key press when the stimulus appeared. The stimulus consisted of a circle of light which appeared at the point of fixation, along with a tone. Participants were to inhibit reaction if the circle of light did not appear, regardless of the occurrance of the tone. Both visual and auditory stimulus intensity were varied, giving a loud, soft, or null tone concurrent with a bright, dim, or null light. The variable of time uncertainty was also manipulated, with either a short or long foreperiod between the warning signal and the stimulus. Reported results indicate that the relationship between time uncertainty and visual stimulus intensity is additive but an interactive relationship was found for time uncertainty and auditory stimulus intensity. An interaction was also found between auditory and visual stimulus intensity, indicating that they affect the same processing stage, as would be expected in Sanders' (1983) model.

Sanders (1975) also investigated the relationship of stimulus intensity and time uncertainty using both auditory and visual stimuli. The auditory stimuli were high, medium, and low tones presented in both ears. Visual stimuli consisted of circular light spots which were high, medium, and low in terms of brightness. Time uncertainty was varied using two different foreperiod durations. Results showed significant additive effects of visual stimulus intensity and time uncertainty. However, a significant interaction was found between auditory stimulus intensity and time uncertainty. These results are similar to those reported by Bernstein et al. (1973). One conclusion Sanders drew from these results was that weak auditory signals are more affected by time uncertainty than loud auditory signals. Put another way, high intensity auditory stimuli may have a rousing capacity which in turn affects response execution.

The relationship between auditory stimulus intensity and time uncertainty has also been found to be additive. Sanders (1977, Experiment 2) presented auditory signals to either the left ear, both ears (sounding as if it were in the middle of the head), or the right ear. Participants gave either a compatible response (pressing a left, middle, or right key after hearing a left, middle, or right-sided signal) or an incompatibe response (middle key response to left ear signal, right key response to middle signal, left key response to right ear signal). Two levels of signal intensity and two levels of time uncertainty were used. Results showed significant, additive effects of stimulus intensity, time uncertainty, and S-R compatability.

Sanders (1977) completed two additional experiments in which participants responded by pressing a key to an auditory stimulus in Experiment 3 or a visual stimulus in Experiment 4. In both experiments there were catch signals presented as well, to which participants were to inhibit their responses. Stimulus intensity and time uncertainty were varied in both experiments. Results of both experiments showed stimulus intensity to have a significant effect on reaction time. An interaction between stimulus intensity and time uncertainty in Experiment 3 confirmed the results of Sanders' earlier study (Sanders, 1975), which found that weak auditory signals are more affected by time uncertainty than loud auditory signals.

The results of these research studies which included stimulus intensity as a variable, have yielded some inconsistencies in the relationship between auditory stimulus intensity and time uncertainty. However results do support a consistently additive relationship for visual stimulus intensity and time uncertainty. It appears that the stimulus intensity variable is affecting an aspect of information processing as Sanders (1983) suggests in his cognitive-energetical model.

Stimulus Quality

Sanders' (1983) stage of feature extraction is hypothesized to be affected by the variable of stimulus quality. The quality of a stimulus in an experimental task is manipulated by degrading the stimulus with some sort of simultaneous masking pattern. This may consist, for example, of a checkerboard pattern, a pattern of nonsense shapes, or a random dot pattern superimposed over the stimulus.

Hochhaus, Williams, and Polk (1989) studied the effects of stimulus quality and letter case in a word naming task. Stimuli consisted of words which were either in all capital letters or mixed case (every other letter was a capital letter) and were either intact or degraded with a slash printed over each letter. Both stimulus quality and letter case significantly affected reaction time in reading the stimulus words. Both the reaction time data and accuracy data showed an interaction between stimulus quality and letter case which would suggest that both of these variables have an affect on Sanders' (1983) feature extraction stage.

Sternberg (1969, Experiment 5) used a digit naming task with the variables of stimulus quality (some of the stimuli were degraded with a superimposed checkerboard mask), S-R compatibility (participants were either to name the digit presented or the digit plus one), and number of alternatives. Significant main effects for both stimulus quality and S-R compatibility were found and their effects on reaction time were additive. Number of alternatives was found to interact with both stimulus quality and S-R compatibility. This suggests that number of alternatives affects both an earlier processing stage in common with stimulus quality (Sternberg refers to this stage as stimulus encoding) and also affects a later stage in common with S-R compatibility (translation and response organization).

A digit naming task was also used by Blackman (1975), in which the stimuli (numbers presented on a stimulus projector) were either intact or degraded with a superimposed checkerboard pattern. Stimulus-response compatibility was also manipulated, with participants responding by verbalizing either the number presented or that number plus one. Results showed that both stimulus quality and S-R compatibility had significant effects on reaction time. The relationship between these two variables was found to be additive.

Frowein and Sanders (1978) conducted a choice reaction time experiment in which stimuli consisted of two lines (one horizontal and one diagonal) joined in one corner, presented on a Nixie tube. There were four response buttons located at each corner (upper right and left and lower right and left) of the Nixie tube. To vary stimulus quality, some of the stimuli were degraded with a superimposed visual noise pattern consisting of nonsense shapes. Stimulus-response compatibility was also varied. In the compatible condition participants responded by pressing the target button that the stimulus pointed to. In the incompatible condition, they pressed the next target button in the counterclockwise position. Time uncertainty was a third variable with two different foreperiods used. They found significant main effects for all three variables which were additive, suggesting that each of these variables affects a different processing stage. Movement time data were collected and analyzed as well as reaction time data. Results of the movement time data indicated that none of the three variables affect movement time, and therefore do not affect response execution.

Using the same experimental task described above, Sanders (1979, Experiment 3) conducted a study to assess the effects of stimulus quality, S-R compatibility, and instructed muscle tension on reaction time. The variable of muscle tension was manipulated by instructing subjects either to stretch the relevant muscle groups for optimal performance or to fully relax the relevant muscle groups. Significant, additive effects on reaction time were found for signal quality and S-R compatability. Sanders (1979) notes that the finding of instructed muscle tension being additive to stimulus quality and S-R compatibility, which are variables affecting input stages in Sanders' model, suggests that instructed muscle tension affects a motor stage of processing.

Van Duren and Sanders (1988) conducted a number naming task in which the stimuli were numerals which were divided into two pairs (e.g. 2,3; 4,5). Stimulus quality was varied by either presenting the digits intact or degrading them with a random dot pattern. S-R compatibility was also manipulated, with participants either naming the digit they saw or naming the other digit of that pair. Stimulus intensity was also varied, with a bright or dim stimulus. All three of these variables were found to have significant effects on reaction time and their effects were additive, supporting the possibility that they affect three separate stages of information processing.

Schwartz et al. (1977) cited above conducted a second experiment because, although the data from Experiment 1 had no significant interactions, it looked interactive when graphed. The method of this second experiment required participants to verbally identify the stimulus presented, which was either the letter A or H. The three variables included in the study were stimulus quality (either intact or degraded with a pattern mask), S-R compatibility (either say the letter presented or the other letter), and stimulus similarity (the similarity between the two letters was varied). A warning signal was given prior to stimulus presentation. The three main effects were found to be significant and their effects on reaction time were addititve.

Salthouse (1981) suggested that results from Schwartz et al. (1977) and those reviewed bv Sanders (1980), showing additive effects of stimulus intensity and stimulus degredation, may suggest that intensity affects the early encoding stage and thus degredation affects a later, comparison or decision stage. An alternative explanation he gives to account for the additivity between these two factors is that they both influence separate perceptual stages. This conclusion is more along the lines of Sanders' (1983) theory, in which the two separate stages of preprocessing (affected by stimulus intensity) and feature extraction (affected by stimulus quality) both occur early on in the information processing sequence.

Stimulus-Response Compatibility

The variable of stimulus-response compatibility (S-R compatibility) is believed to affect a third processing stage - that of response choice. This variable has to do with the closeness in mapping between the given stimulus and the required response. Varying S-R compatibility involves finding both a response that seems very natural, or compatible to the stimulus and a response that seems incompatible, often an opposite type of response. One issue with the S-R compatibility variable is that some compatible tasks may be more natural or overlearned than others, which may contribute to some conflicting results that exist in the literature.

One example of research using the variable of S-R compatibility can be found in Salthouse (1981, Experiment 4). The stimuli consisted of arrows pointing to the lower left or lower right of a video monitor. Participants were to press a button that the arrow pointed to (compatible condition) or press the opposite button (incompatible condition). S-R compatibility was found to have a significant effect on reaction time.

Hasbroucq, Guiard, and Kornblum (1989) used a tactile reaction time task in which the stimuli consisted of brief mechanical taps to the fingers. The same mechanisms whichprovided the taps were also used as the response buttons. S-R compatibility was varied by having the participant respond either by pushing the response button with the finger that was tapped (compatible) or with the other finger (incompatible). Stimulus intensity was varied as well with the force of the tap being strong or weak. A third variable used in this study was that of finger repertoire, with three levels (within hand - thumb and index finger of the left hand; between hands - thumb of left and right hands; between hands/between fingers - left thumb and right index finger). They cite research which has found finger repertoire to affect motor programming. Results show the three variables to be additive in their effects on reaction time. Given that stimulus intensity is thought to affect an early stage in information processing, and finger repertoire affects motor programming, then it appears a logical conclusion that S-R compatibility (which is additive to these two variables and therefore affecting a third stage) affects a stage which occurs between the other two. This supports Sanders' (1983) notion of S-R compatibility affecting a response choice stage, which falls in the sequence of stages between stimulus preprocessing and motor adjustment.

An experiment by Sanders (1970) was designed to study S-R compatibility and to see if that variable is independent of a motor preparation stage. His task consisted of presenting a vowel as the stimulus. Responses not set up for motor preparedness were ones in which the participant was to respond by saying the vowel presented and adding an S sound on the end (presented with A say AS). Motor preparedness was achieved by having the participants say the vowel presented with an S sound before it and after it (presented with A say SAS) so that they could be prepared with saying the initial S sound even before knowing what vowel would be presented. S-R compatiblility was also varied so that in the compatible condition participants were to use the stimulus vowel as the vowel in their response. The incompatible condition required subjects to respond using the vowel which comes next in the alphabet following the vowel presented as the stimulus (eg., given A say E). The main effects of both S-R compatibility and motor preparedness were significant and these two variables were additive in their effects on reaction time. This suggests that S-R compatibility is a variable which is independent of a motor preparation stage, supporting the distinction in Sanders' (1983) cognitive-energetical model in which there is both a response choice stage and a motor adjustment stage.

Time uncertainty, which will be discussed separately below, is a variable that is often combined in research with S-R compatibility. It is thought to affect the motor adjustment stage, and is typically found to be additive to S-R compatibility. An exception to this is found in Broadbent and Gregory (1965), who had participants complete a tactual choice reaction time task in which the stimuli consisted of vibrations to fingers. S-R compatibility was varied with participants either pressing down with the stimulated finger (compatible condition) or pressing down the corresponding finger of the other hand (incompatible condition). Participants completed a 2-choice reaction task one day, using either the index or middle fingers from both hands. The other day they completed a 4-choice session in which they used the index and middle fingers from both hands. Time uncertainty was varied with a stimulus either occurring about 2 seconds after a verbal warning or occurring with no warning at varying time intervals (10, 20, 30, or 40 seconds apart). Results showed an interaction between S-R compatibility and time uncertainty, which is contrary to Sanders' (1983) belief that those variables affect two separate stages and should be additive in their effects on reaction time.

Other studies have shown that S-R compatibility and time uncertainty are additive. For example, Posner et al. (1973, Experiment 1) used a visual task to assess the relationship between S-R compatibility and time uncertainty. Participants watched for the stimulus, an X, which appeared either to the right or the left of a vertical line at the center of an oscilloscope. In the compatible condition, participants pressed the left key when the X appeared to the left of center and the right key when it appeared to the right. In the incompatible condition, they pressed the key on the side opposite that where the stimulus appeared. Time uncertainty was varied with different foreperiod durations prior to the presentation of the stimulus. The results of this study show that S-R compatibility and time uncertainty are additive in their effects on reaction time. As previously cited, support for the additivity of S-R compatibility and time uncertainty was also found by Frowein and Sanders (1978).

Sanders (1977) was intrigued by the contradiction between Broadbent and Gregory's (1965) finding of an interaction in the effects of S-R compatibility and time uncertainty on reaction time and other results suggesting that these variables are additive. In order to clarify this discrepancy, he tested the relationship between foreperiod duration and S-R compatibility using both a visual choice-reaction task and an auditory choice-reaction task. The visual task consisted of three lights and response keys mounted on a sloping desk. Participants kept their index, middle, and ringfinger on the response keys pressing the key beneath the presented light in the compatible condition. To correctly respond in the incompatible condition, the middle key was to be pressed in response to the left light, the right key for the middle light, and the left key for the right light. Time uncertainty was varied with three different foreperiods occurring between an auditory warning signal and the stimulus light.

The auditory task involved signals being presented to the left ear only, to both ears (sounding to the participant as though it occurred in the middle of the head), or to the right ear only. Participants were to respond by pressing a key which corresponded spatially to the location of the sound (sound in left ear, press left key, etc.) in the compatible condition. The incompatible response was to press the middle key when the signal was in the left ear, the right key when the signal was in the middle, and the left key when the signal was in the right ear. Time uncertainty was varied by either receiving a constant 1-second interval between the warning signal and the stimulus or a variable interval (1, 3, 5, 7, or 9 seconds). Stimulus intensity was also varied with the auditory signals being either 35 or 85 decibles.

In both of these experiments foreperiod duration and S-R compatibility were found to be additive in their effects on reaction time. Stimulus intensity, which was included in Experiment 2, was additive as well. Some possible explanations were offered by Sanders (1977) for the discrepancy between his results (and others that supported additivity of those variables, such as those reviewed above) and those of Broadbent and Gregory (1965). He suggests one possible explanation is that there is simply a difference between tactual signals and visual or auditory signals. This implies the presence of a more complex interaction taking place - a modality (tactual signals vs. visual signals) x S-R compatibility x time uncertainty interaction. Another possible explanation is that there is a different degree of compatibility for tactual-choice responses than for responses corresponding spatially to visual or auditory signals. The reaction time-information function has a zero slope for the tactual choice responses (Leonard, 1959), meaning that reaction time does not increase as a function of an increased number of possible tactual responses. In other words, pressing down a finger that has been tactually stimulated is such a compatible response that reaction time will not be affected by increasing the task, for example, from using just two fingers to using eight fingers.

Sanders suggests that a way to determine which one of these explanations is accurate would be to complete an experiment using the naming of letters as the task. This task is one that, like the tactual task, is so overlearned it has the property of zero slope of the reaction time-information function. If the results of the letter-naming task showed S-R compatibility and time uncertainty to be interactive, Sanders suggests it would mean that a different structure of processing stages for extremely compatible signal-response connections exists. However, if results from such an experiment showed an additive relationship between S-R compatibility and time uncertainty, then the more complex modality x S-R compatibility x time uncertainty interaction may be the best explanation of Broadbent and Gregory's (1965) results. The current study is designed to address this issue.

Time Uncertainty

Time uncertainty is the variable suggested to affect the fourth of Sanders' (1983) information processing stages, that of motor adjustment. One common way to define time uncertainty is to have the foreperiod consistent at times and varied at other times. Another way to vary time uncertainty is to have some trials with a short delay before the stimulus is presented and other trials with a long delay. Several experiments using time uncertainty as a variable have been reviewed above (Bernstein et al., 1973; Broadbent and Gregory, 1965; Frowein and Sanders, 1978; Posner et al., 1973; Sanders, 1975; Sanders, 1977).

Additional studies include one by Sanders (1979, Experiment 1) in which he tested the effects of instructed muscle tension and time uncertainty on reaction time, using the same experimental paradigm as in his Experiment 3 (reviewed above). Time uncertainty was manipulated using two different foreperiods between the warning signal and the presentation of the stimulus. The main effect of foreperiod duration was significant. A significant interaction found between foreperiod duration and instructed muscle tension supports the idea that time uncertainty affects a motor adjustment stage, since muscle tension was also assumed to affect a stage involving motor preparation.

Spijkers (1990) studied the relation between response specificity (the angle of the movement direction from the starting position to a target), foreperiod duration, and S-R compatibility. Results showed that response specifictiy interacted with foreperiod duration but did not interact with S-R compatibility. This suggests that response specifictiy is involved in the stage related to readiness of the motor system, as is foreperiod duration, instead of response choice like the S-R compatibility variable.

An experiment considering the effects of signal modality and foreperiod duration on reaction time was conducted by Sanders and Wertheim (1973). Participants completed experimental blocks in which the stimuli were auditory and others in which visual stimuli were used. For the auditory stimuli, participants were instructed to press the response button on the top if the tone was high and on the bottom if the tone was low. In the visual task, participants pressed a response button on the left if the stimulus light appeared on the left or on the right if the right stimulus light lit up. Foreperiod duration was varied with three different foreperiods occurring between a warning signal and the stimuli. The expected significant main effect of foreperiod duration was obtained. There was also a significant interaction between foreperiod duration and modality, suggesting that stronger arousing signals (auditory signals) are less affected by time uncertainty than the weaker arousing visual stimuli.

Summary of Evidence

Several attempts have been made throughout the years to develop a model which is sufficient to explain how humans process information. Because the mechanisms of information processing cannot be directly observed, they must be studied indirectly and inferred from the results of research such as that discribed above. These experiments most often use reaction time measurements as the dependent variable which is affected by various manipulations of the stimuli. The primary goal of an information processing model is to account for the results of these reaction time experiments. Two well-known, early approaches to explaining information processing, the subtraction method (Donders, 1868/1969) and the additive factor method (Sternberg, 1969), have been criticized for violations of the basic assumptions inherent in their methodologies. However, they have been useful in generating a large amount of research in the area as well as spurring the development of some alternative models of information processing.

Sanders (1983) cognitive-energetical model is one such alternative. Four stages involved in information processing are proposed along with four experimental variables which appear to tap into these stages. As can be seen from the review of the literature above, much of the research that has been done has incorporated Sanders' (1983) variables one or two at a time. A few studies have used three of Sanders' variables. For example, Everett, Hochhaus, and Brown (1985) varied stimulus intensity, stimulus quality, and S-R compatibility. Stimuli for the task were letters of the alphabet presented on the video monitor. Participants were instructed to name the letter presented (compatible condition) or, for the incompatible condition, name the next letter of the alphabet (shown letter A, say B). The display on the video monitor was either at a low intensity or a high intensity. Finally, the stimuli were either intact or degraded with a checkerboard mask. All three variables were found to have significant, additive effects on reaction time, supporting Sanders' (1983) notion of the three stages of preprocessing, feature extraction, and response choice. The authors also had a fourth variable, that of practice, which was also additive in terms of its effects on reaction time. This suggests that it may therefore be affecting the fourth, motor adjustment stage suggested by Sanders (1983). Other examples of experiments which included three of the variables suggested as markers for Sanders' (1983) four stages were reviewed above (Sanders, 1977; Frowein and Sanders, 1978; and Van Duren and Sanders, 1988). However, lacking in this body of research are experiments incorporating all four of Sanders' variables simultaneously. Such studies are necessary in order to provide the most stringent test of Sanders' cognitive-energetical model, and thus to provide convincing support for the existence of his four stages of information processing.

The current research effort is designed to include the four variables of stimulus intensity, stimulus quality, stimulus-response compatibility, and foreperiod duration in order to assess whether these four variables do have independent, additive effects on reaction time as suggested by Sanders (1983). The rationale for a single-experiment approach to testing the model is as follows. First, such an approach would appear to be most efficient, gathering the maximum amount of data per research participant. Secondly, the large amount of data gathered will increase the reliability of the findings. A third reason for the single-experiment approach is that it will make it possible to examine previously untested three-way and four-way interactions. Finally, including all four variables in one experiment should stress the model to its limits, and thus should provide a better test of the model than has been previously performed.

Based on Sanders' (1983) theory and previous existing data, the primary experimental question will be whether stimulus intensity, stimulus quality, stimulus-response compatibility, and foreperiod duration have additive, non-interacting effects on reaction time in a letter-naming task. If such is the case, the most convincing support for Sanders' model of information processing yet available, will be obtained. If not, it may be that the four stages which make sense intuitively will not prove to be robust in terms of direct experimental evidence.

A second experimental question is related to a discrepancy in the literature reviewed above. A study by Broadbent and Gregory (1965) suggests an interactive relationship between the variables of S-R compatibility and time uncertainty. Results of several other studies (Posner et al., 1973, Frowein and Sanders, 1978, and Sanders, 1977) support Sanders' (1983) theory that these two variables are additive in their effects on reaction time. Sanders (1977) suggests that this discrepancy may be due to a difference between tactual signals (used by Broadbent and Gregory, 1965) and the more commonly used visual and auditory signals. In other words, there may be a modality x S-R compatibility x time uncertainty interaction taking place. A second possible explanation offered by Sanders (1977) is that there may be a different degree of compatibility for tactual stimuli, since the reaction time-information function for tactual choice responses has a zero slope.

One way to determine which one of these explanations is accurate would be to conduct another experiment in which the task had the property of a zero slope reaction time-information function. One such task is letter naming, which is used in the following experiment. If results show an interaction between S-R compatibility and time uncertainty, then this would support the explanation that the difference in degree of compatibility for highly overlearned stimuli affects the information processing sequence. However, if S-R compatibility and time uncertainty are additive, then Sanders (1977) suggestion that there is simply a difference between tactual signals and other types of signals would be supported. Given that we do not know how highly overlearned visual stimulus events interact with time uncertainty, the four-factor additivity predicted by Sanders' (1983) model may require qualifications in the case of S-R compatibility and time uncertainty.

CHAPTER III

METHOD

Participants

The participants used for this experiment were 40 undergraduate students enrolled in introductory psychology classes at a large, midwestern university. They were given extra credit in their psychology course in exchange for their participation. Participants were told that they were being asked to engage in an experiment regarding how people process information. They were informed that they would be tested individually, using a computer task, and the experiment would require approximately one hour of their time. All participants were treated in accordance with the "Ethical Principles of Psychologists" (American Psychological Association, 1981).

Apparatus

The stimuli, consisting of block letters, were generated by means of an Apple II microcomputer, modified according to Reed (1979). His modification makes it possible to obtain precise timing (within 1 millisecond) of response signals and latencies. A Samsung video display monitor, model MD-1255H, was used to present the letters.

In order to simplify the division of the number of stimuli into different conditions, only 24 letters of the alphabet were used for the block letters (A and Z were excluded). The twenty-four block letters were white, measuring 2.7 x 2 cm, and projected on a video screen measuring 15 x 19.5 cm. The variable of stimulus intensity was controlled by a device described by Hochhaus, Carver, and Brown (1984). The two intensity measurements, high and low, were consistent with those described by Everett et al. (1985). Luminance values were hence set at approximately 0.03 cd/m^2 (background) and 141.5 cd/m^2 (figure) in the high intensity condition and 0.03 cd/m^2 (background) and 3.77 cd/m^2 (figure) in the low intensity condition. Stimulus quality, a second variable, was manipulated by superimposing a black and white checkerboard mask over the stimulus letter. The mask used to degrade the stimulus measured 2.5 x 2 cm., with an individual square within the mask measuring 5 x 4 mm.

In order to detect participants' verbal responses, a sound-activated relay device was used. Finally, a software clock (Price, 1979) was used to record all of the vocalization latency measures. Vocalization latency (reaction time) is the time period from the onset of presentation of the block letter stimulus to the onset of the participants' vocal response. Foreperiod duration was used to manipulate the variable of time uncertainty. In most experiments, the foreperiod follows a warning signal of some sort. In the present study, it was decided to use a word instructing the participants about the required response (SAME, PRIOR, or NEXT) instead of a meaningless signal of some sort. Foreperiod duration, then, is defined as the time period from the offset of the instruction word to the onset of the visual stimulus. Values of 50 ms. and 2.5 seconds were used. The timing of foreperiod duration was controlled within the computer by adjustments in the limits of a dummy loop.

Procedure

Each participant came to the laboratory for approximately one hour to complete the letter-naming task. They began by completing a practice block (48 trials) and then completed the three experimental blocks (144 trials). In order to increase the likelihood of participation, the decision was made to include a relatively large sample size and have a lower number of trials per condition than is often used. Each block consisted of the presentation of 48 letters (48 trials). Within each block, each of the 24 letters was presented twice in random order. The participants were given a brief break between the practice block and the first experimental block, as well as between each of the three experimental blocks, in order to maintain maximum effort on the part of the participants. Between experimental Blocks 1 and 2, the half way point of the experiment, the participants were asked to walk down the hall and back to ensure adequate time to rest their eyes.

Participants were seated at the computer to complete the letter-naming experiment. They were instructed to watch the monitor screen on which the response instructions were shown briefly before each letter trial. The response instruction indicated that they were to do one of three things: 1) "SAME" - they were to vocalize the letter that appeared before them on the screen (the compatible condition - if participant saw the letter "B", they were to say "B"); 2) "NEXT" - they were to verbalize the letter that comes next in the alphabet following the letter they saw on the screen (the following letter condition - if the participant saw the letter "B" they were to say "C"); 3) "PRIOR" - they were to vocalize the letter that appears in the alphabet immediately before the one shown on the screen (the prior letter condition - if the letter on the screen was "B" they were to say "A"). In this way, the variable of stimulus-response compatibility was manipulated.

The foreperiod duration following these instructions varied randomly between the immediate condition and the delayed condition. The immediate condition was one in which the stimulus followed the instructions by 50 ms. and in the delayed condition, the stimulus followed after 2.5 seconds. The participant was told that once a letter appeared on the screen, they were to verbalize the instructed response into the microphone in front of them as quickly as possible while keeping their errors at a minimum. The stimulus remained on the screen until the sound-activated relay device registered a response. To keep track of a participant's accuracy, the experimenter typed the participants' responses into the computer after the response was given. If the response given was incorrect, participants received feedback with a "beep" sound from the computer. After each trial, their current percent correct was flashed briefly on the screen. Participants who made negative comments about their performance were encouraged with reassurance that the task is indeed a difficult one for everybody. The computer screen would then go blank and the experimenter would press the space bar to begin the next trial.

Following each block of the task, participants were given feedback, shown on the monitor screen, based on accuracy. They were instructed to speed up if errors were less than 2%, to stay the same speed if errors equaled 2%, or to slow down if errors were greater than 2%. After the final experimental block, participants were given additional information as to the nature of the experiment. They were encouraged to verbalize strategies they used in completing the task, and were asked about what aspects of the task were relatively difficult or easy for them. They were then thanked for their assistance and were free to leave.

CHAPTER IV

RESULTS

To test the stage model, the two dependent variables of reaction time and accuracy were analyzed using a 2 x 2 x 3 x 2 analysis of variance for each. The analyses included the data from each of the three experimental blocks for each participant but did not include data from the practice block. All error trials were excluded so that mean reaction time was based on correct trials only. Also, any trial which had a reaction time of only one millisecond was excluded, because these represented trials in which the equipment responded to some extraneous noise instead of the participant's actual verbal response.

The four independent variables of stimulus intensity, stimulus quality, stimulus-response compatibility, and foreperiod duration were within-subjects variables. All main effects and interaction terms were evaluated in repeated measures analyses of variance. Based on the results of the first ANOVAs for each dependent variable, the decision was made to remove the Prior level of stimulus-response compatibility and to run the ANOVAs again as a 2 x 2 x 2 x 2 design. Results of the two analyses of variance using reaction time as the dependent variable will be discussed first, followed by results of the ANOVAs using accuracy scores.

Reaction Time

Initial Analysis

A 2 x 2 x 3 x 2 (stimulus intensity - low vs. high, stimulus quality - no mask vs. mask, stimulus-response compatibility - prior vs. same vs. next, and foreperiod duration - immediate vs. delayed) analysis of variance with reaction time as the dependent variable was completed initially. The F values are listed in Table V, in the appendix. All four main effects were found to be significant. A significant main effect was confirmed for the variable of stimulus intensity, $F(1,39) = 22.22$, $p < 0.0001$. As can be seen in the table of means (Table I), participants' mean response time was significantly faster in the high intensity condition than in the low intensity condition. The second significant main effect was that of stimulus quality, $F(1,39) = 10.76$, $p < .01$. The means indicate that responses were significantly faster when there was no mask degrading the stimulus. A third main effect, that of stimulus-response compatibility, was also significant, $F(2,78) = 192.55$, $p < 0.0001$. Means reveal that, as expected, reaction times were fastest in the same condition (876 ms.) and slowest in the prior condition (2167 ms.), with the next condition falling in the middle (1567 ms.). Finally, the main effect of foreperiod duration was significant, $\underline{F}(1,39) = 7.74$, $\underline{p} < .01$. Participants responded faster when the stimuli were presented immediately following the response instructions and slower when there was a delay prior to the presentation of the stimuli.

TABLE I

MEANS FROM INITIAL ANALYSIS
REACTION TIME

	M	SD
Stimulus Intensity		
HIGH	1464.25	743.49
LOW	1604.12	814.14
Stimulus Quality		
NO MASK	1498.55	798.98
MASK	1569.82	803.48
S-R Compatibility		
PRIOR	2167.85	769.70
SAME	867.62	291.48
NEXT	1567.08	636.22
Foreperiod Duration		
IMMEDIATE	1497.10	772.50
DELAY	1571.26	828.84

Although the stage model would predict no significant interactions, three interactions (one two-way and two three-way interactions) were found to be significant in the current experiment. One two-way interaction, that of stimulus intensity by stimulus quality, was significant, $\underline{F}(1,39) = 7.18$, $\underline{p} < .05$. The reaction time means (see Table IX in the appendix) reveal that in the low intensity condition, reaction times to intact stimuli were much faster than those for stimuli degraded with the mask. However, in the high intensity condition reaction times were nearly the same for degraded and intact stimuli.

A second significant interaction was that of stimulus intensity by stimulus quality by stimulus-response compatibility, $\underline{F}(2,78) = 3.35$, $\underline{p} < 0.05$. The reaction times were slowest in the prior condition, faster in the next condition, and fastest in the same condition, as expected. An unexpected result occurs in the prior condition. Means show that when the screen was at high intensity, reaction times were slower when the stimuli were intact and faster when the stimuli were degraded.

The final significant interaction was that of stimulus intensity by stimulus quality by foreperiod duration, $\underline{F}(1,39) = 10.99$, $\underline{p} < .01$. Means show that with the high intensity screen and stimuli presented immediately, reaction times were faster with a mask degrading the stimuli than they were when the stimuli were intact.

Because several interactions reached the level of significance which is not predicted by Sanders' (1983) model, the possibility was considered that perhaps adding the third level (prior condition) of the stimulus-response compatibility variable made the task too complex and difficult for the participants. It may be that this added complexity was affecting results for all of the independent variables. Therefore, the decision was made to remove the prior condition and complete the analysis of variance again with the reaction time data.

Second Analysis

For this analysis of variance, the prior condition data were removed from the stimulus-response compatibility variable, making it a two-level variable, leaving a 2 x 2 x 2 x 2 design. The F values for this analysis are reported in Table VI in the appendix. This ANOVA also yielded significance in all four of the main effects. The main effect of stimulus intensity reached significance with $F(1,39) = 36.84$, $p < .0001$. Reaction times were significantly faster when the video monitor was at the high intensity level. As in the prior analysis, a significant main effect was obtained for stimulus quality, $F(1,39) = 7.16$, $p < 0.05$, with reaction times significantly faster in the no mask condition than in the mask condition (see Table

II below for a list of means). The main effect for stimulus-response compatibility remained significant, $F(1,39) = 107.76$, $p < 0.0001$, even without the third level. As can be seen in the table of means (see Table II), reaction times for the same condition were significantly faster than those for the next condition.

TABLE II

MEANS FROM SECOND ANALYSIS
REACTION TIME

	M	SD
Stimulus Intensity		
HIGH	1144.42	581.54
LOW	1290.28	621.51
Stimulus Quality		
NO MASK	1186.04	628.76
MASK	1248.65	581.22
S-R Compatibility		
SAME	867.62	291.48
NEXT	1567.08	636.22
Foreperiod Duration		
IMMEDIATE	1188.09	586.23
DELAY	1246.60	624.30

Finally, a significant main effect for foreperiod duration was obtained, $F(1,39) = 6.66$, $p < 0.05$, with faster reaction times when stimuli were presented immediately.

In the second (2 x 2 x 2 x 2) analysis of reaction time data, only one of the interaction terms was significant (see Table VI in the appendix). The three-way interaction of stimulus intensity by stimulus quality by foreperiod duration remained significant, $F(1,39) = 10.49$, $p < 0.01$. As before, with a high intensity screen and stimuli presented immediately, reaction times were faster when a mask degraded the stimuli (see Table X in the appendix). Also contrary to expectations were the slower reaction times when stimuli were presented immediately in the conditions of a low intensity screen and a mask degrading the stimuli.

Accuracy

Initial Analysis

The second set of analyses uses accuracy scores as the dependent variable. The first ANOVA using accuracy scores was run with the 2 x 2 x 3 x 2 design, including all three levels of the stimulus-response compatibility variable. The F values for all of the main effects and interactions are reported in Table VII in the appendix. Significant main effects were found for two of the four independent variables. One significant main effect was that of stimulus intensity, $F(1,39) = 13.24$, $p < 0.001$. Means (see Table III) indicate that participants were significantly more accurate in their responses in when the stimuli were presented in the high intensity condition and less accurate in the low intensity condition. The other significant main effect was that of stimulus-response compatibility, $F(2,78) = 21.36$, $p < 0.0001$. Participants' responses were most accurate in the same condition and least accurate in the prior condition, with accuracy in the next condition falling in between.

Two three-way interactions reached significance. One of these significant interactions was the stimulus intensity by stimulus quality by foreperiod duration interaction, $F(1,39) = 8.02$, $p < 0.01$. Looking at the means (see Table XI, appendix) it can be seen that when the video screen was at the high intensity, responses were most accurate in the immediate condition when the stimuli were degraded with a mask. However, they were most accurate in the delay condition when the stimuli were intact. With the screen at the low intensity condition the opposite was true. Responses were most accurate in the delay condition when the stimuli were degraded with a mask and most accurate in the immediate condition when the stimuli were intact.

TABLE III

MEANS FROM INITIAL ANALYSIS
ACCURACY - PERCENT CORRECT

	M	SD
Stimulus Intensity		
HIGH	94.50	0.646
LOW	92.39	0.726
Stimulus Quality		
NO MASK	92.90	0.685
MASK	93.90	0.694
S-R Compatibility		
PRIOR	90.15	0.829
SAME	97.13	0.466
NEXT	93.07	0.661
Foreperiod Duration		
IMMEDIATE	93.68	0.685
DELAY	93.22	0.695

The other significant interaction was that of stimulus quality by S-R compatibility by foreperiod duration, $F(2,78) = 4.10$, $p < 0.05$. In the same and next conditions, responses were more accurate in the immediate condition with a mask degrading the stimuli but more accurate in the delay condition when the stimuli were intact. However, the opposite was true in the prior condition. Responses were most accurate in the delay condition when a mask degraded the stimuli and most accurate in the immediate condition when the stimuli were intact.

Second Analysis

As with the reaction time data, the third level (prior condition) of the stimulus-response compatibility was removed and a 2 x 2 x 2 x 2 ANOVA with accuracy as the dependent variable, was run. See Table VIII in the appendix for the F values. This ANOVA yielded two significant main effects. The main effect of stimulus intensity remained significant, $F(1,39) = 15.27$, $p < 0.001$, with responses significantly more accurate in the high intensity condition (see Table IV). The main effect of stimulus-response compatibility remained significant also, $F(1,39) = 18.09$, $p < 0.0001$. Means (see Table IV) show that participants were significantly more accurate in the same letter condition than in the next letter condition.

Although none of the interactions reached significance, the stimulus intensity by stimulus quality by foreperiod duration was nearly significant, $F(1,39) = 3.66$, $p < .07$. Means (see Table XII, appendix) show that with the high intensity screen and a mask degrading the stimuli, as well as the low intensity screen in both the mask and no mask conditions, responses were more accurate when stimuli were presented immediately. However, with the high intensity screen and no mask degrading the stimuli, responses were more accurate in the delay condition.

TABLE IV

MEANS FROM SECOND ANALYSIS
ACCURACY - PERCENT CORRECT

	M	SD
Stimulus Intensity		
HIGH	96.30	0.528
LOW	93.90	0.629
Stimulus Quality		
NO MASK	94.27	0.618
MASK	95.93	0.545
S-R Compatibility		
SAME	97.13	0.466
NEXT	93.07	0.661
Foreperiod Duration		
IMMEDIATE	95.36	0.582
DELAY	94.84	0.588

CHAPTER V

DISCUSSION

Our knowledge of human information processing has progressed over the past 160 years due to a continuous research effort. As more data become available, more theories are developed to attempt to account for the results. Sanders' (1983) cognitive-energetical model is one such theory. As a theory, it is exceptional in the range of experiments it attempts to explain succinctly.

Sanders asserts that the four variables of stimulus intensity, stimulus quality, stimulus-response compatibility, and foreperiod duration are markers for four independent stages involved in information processing. An assumption of his model is that these four variables will have additive, non-interacting effects on the dependent variable of reaction time. A large body of research has been done incorporating these four variables, typically two at a time. Most of the results support the notion that these variables have additive, non-interacting effects on reaction time. The focus of the present study was to provide the most rigorous test of the model by including all four variables and to discover whether the results would support Sanders' (1983) theory. Both reaction time data and accuracy scores were used as dependent variables in analyzing the data from the present experiment.

Another experimental question was designed to answer a question posed by Sanders (1977) about a discrepancy in the literature related to the relationship between the variables of S-R compatibility and time uncertainty. This question is whether there is a difference between tactile signals and other types of signals (e.g., auditory, visual) or whether highly overlearned responses (such as tactile choice responses and the naming of letters) have a different degree of compatibility than other responses, thereby affecting the information processing sequence.

A Stringent Test of Sanders' Model

The initial purpose of this study was to provide the most stringent test of Sanders' cognitive-energetical, four-stage model. This was done by including in one experiment all four of the variables suggested by Sanders as the markers for his four proposed processing stages. The initial analysis found all four of the independent variables to have a significant effect on reaction time which is supportive of the stage model being tested However, these initial results also showed one significant two-way interaction and two significant three-way interactions. The presence of any significant interactions contradicts Sanders' notion that the four variables have additive, non-interacting effects. Thus, the initial analysis of the reaction time data did not support Sanders' model. The results from the initial analysis using accuracy data as the dependent variable do not suggest that participants were making speed accuracy trade-offs which would interfere with the validity of the results.

In trying to understand the reason for so many significant interactions in this initial analysis, the possibility was considered that adding a third level (prior condition) to the S-R compatibility variable may have made the task too difficult for the participants. For that reason, the prior condition data were removed and the data were analyzed again with just two levels of the S-R compatibility variable. In this second analysis, all four of the main effects were again significant, suggesting that the present experimental task is a good one for testing Sanders' (1983) four-stage model. The accuracy data confirmed that participants were using a good approach to completing the task accurately and quickly.

The second analysis is still not fully supportive of Sanders' cognitive-energetical four-stage model because it contained one significant interaction term. It is likely that the task used in this study was too difficult due to including three levels of S-R compatibility. Although the third (prior) level of the S-R compatibility variable was statistically removed, it is impossible to know how this complex task affected participants' performance on the same and next compatibility conditions. The effects were probably too general to be removed by simply taking out the third level of S-R compatibility in the analysis. A repetition of the present study with an easier task (i.e., two levels of the S-R compatibility variable) is likely to provide full suport for the four-stage model.

S-R Compatibility and Time Uncertainty Relationship

The second research question addresses some discrepant results which exist in the literature regarding the relationship between the variables of S-R compatibility and time uncertainty. Many studies show that these variables are additive in their effects on reaction time. However, Broadbent and Gregory (1965) found their relationship to be interactive. Sanders (1977) offered some possible explanations for those results. He suggested it may be that tactile stimuli, which Broadbent and Gregory used, are simply different than other types of stimuli. If this is the case, then there is a more complicated modality (tactile vs. other types of stimuli) x S-R compatibility x time uncertainty interaction taking place. Another possible explanation is that there is a different degree of compatibility for highly automatic, overlearned stimuli such as tactile stimuli. Stimuli such as this have the property of a zero slope reaction time-information function, so that reaction time does not increase as a function of an increased number of possible responses.

Sanders (1977) suggests that a study using letter naming as the task could distinguish between these two possible explanations because the letter naming task also has this zero slope property. The present study used a letter naming task. Results show that the variables of S-R compatibility and foreperiod duration both have significant effects on reaction time. Their effects are additive and they do not interact. This supports the first explanation of the results obtained by Broadbent and Gregory (1965). Tactile stimuli are apparently different than other types of stimuli so that when they are used there may be an additional modality variable which enters into the information processing sequence. The present study used the highly overlearned letter-naming task and did not find a S-R compatibility x foreperiod interaction. These results therefore rule out the explanation of Broadbent's and Gregory's interaction based on the automatic character of responses to tactile stimuli.

Summary and Conclusions

The purpose of the present study was to test Sanders' (1983) cognitive-energetical model. The present experiment was designed to put the maximum stress on the model, including all four of Sanders' suggested variables. Although the obtained results cannot be fully explained by Sanders' model due to one significant interaction, they are highly supportive of the four-stage model. In the present study, three levels of the S-R compatibility variable were used initially, in order to gain some additional information. Inconsistencies in the results suggested that this was probably too difficult a task for the participants, so in the final analyses the third level of the variable was dropped. Sanders' (1983) theory incorporates the notion of an energy source used by each stage. The results of the present experiment might suggest that an inordinate amount of effort (the energetical mechanism directly influencing the response choice stage) was used due to the difficulty of the S-R compatibility variable which affects this stage. It would be beneficial to repeat the present experiment using just two levels of the S-R compatibility variable.

Continued advancement of our knowledge about the ways in which we process information is interesting, in part, just to understand more about the mechanisms involved. However, a major benefit of having this knowledge is that it can then be extended to help us understand what things in our lives affect our processing ability and what aspects of our lives are affected by it. For example, variables such as doses of a drug, nicotine deprivation, and sleepiness could be expected to impact on a persons information processing ability. Casal, Caballo, and Cueto (1990) did a study in which they had participants classified as morning people (more alert in the morning) or evening people (more alert in the evening) based on a self-report questionnaire. Participants completed several tasks either early in the morning or late at night. One of the tasks was a perceptual-motor task on a computer for which reaction time was the dependent variable.

Results of this study showed that reaction time was significantly affected by the time of application of the task (ie. participants classified as morning people were significantly slower when completing the task at night and those classified as evening people were significantly slower in the morning). By including a similar variable in the present experiment, one could assess which one of Sanders' (1983) stages the alertness variable interacts with. Therefore, it could be determined if this alertness primarily affects the initial, perceptual stages or the later, motor stages. Indeed, Sanders (1983) reviews some evidence which suggests that sleep state affects both the feature extraction and the motor adjustment stages.

Although we have advanced far beyond Bessel's personal equation, there continues to be a fascination with individual differences. Differences such as personality variables impact on the way we process information. In observing participants take part in the present task, it was noted that some let their anxiety about the task affect their performance accuracy and others let their need to be perfect affect their response speed. Many variables such as these impact on our ability to process information. An example of research on how personality variables affect information processing is that of a study done by Orlebeke, Van der Molen, Dolan, and Stoffels (1990). They had participants complete the Disinhibition subscale of the Sensation Seeking Scale (Feij and Van Zuilen, 1984). The participants then completed a reaction time task in which stimulus quality, S-R compatibility, and time uncertainty were all varied.

In the Orlebeke et al. (1990) study, Disinhibition was found to interact with S-R compatibility. The authors conclude that these results indicate that the personality variable of Disinhibition affect the decision stage (or response choice as Sanders, 1983, calls it) of information processing. A logical extension of the present study would be to include some measures of personality variables and assess the ways in which they affect human information processing. It is only through a continued research effort using a model such as Sanders' cognitive-energetical model, that we can add to our knowledge base on human information processing.

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APPENDIXES

TABLE V

ANALYSIS OF VARIANCE: REACTION TIME INITIAL ANALYSIS

Source	df	SS	F	Pr>F
Reaction Time				
Main effects:				
SI[a]	1	4695184.13	22.22	0.0001*
Error	39	8240614.57		
SQ[b]	1	1219016.33	10.76	0.0022*
Error	39	4417985.04		
FD[c]	1	1319944.17	7.74	0.0083*
Error	39	6652454.19		
S-R C[d]	2	271016901.10	192.55	0.0001*
Error	78	54893261.14		
Two-way interactions:				
SI*SQ	1	966153.15	7.18	0.0108*
Error	39	5251081.22		
SI*FD	1	20692.55	0.13	0.7223
Error	39	6295593.49		
SQ*FD	1	342430.37	1.73	0.1955
Error	39	7697551.99		
SI*S-R C	2	123651.05	0.48	0.6221
Error	39	10098478.36		
SQ*S-R C	2	268693.91	1.16	0.3189
Error	39	9035526.33		
FD*S-R C	2	140895.27	0.57	0.5702
Error	78	9711300.97		
Three-way interactions:				
SI*SQ*FD	1	1086693.12	10.99	0.0020*
Error	39	3856567.59		
SI*SQ*S-R C	2	628704.31	3.35	0.0402*
Error	78	7317357.43		
SI*S-R C*FD	2	315483.81	1.06	0.3522
Error	78	11631827.26		
SQ*S-R C*FD	2	1007469.50	2.72	0.0722
Error	78	14451765.74		

TABLE V (continued)

Source	df	SS	F	Pr>F
Four-way interaction:				
SI*SQ*S-R C*FD	2	165219398.99	0.40	0.6686
Error	78	8226909.25		

[a] SI = Signal Intensity
[b] SQ = Signal Quality
[c] FD = Foreperiod Duration
[d] S-R C = Stimulus-Response Compatability

TABLE VI

ANALYSIS OF VARIANCE: REACTION TIME SECOND ANALYSIS

Source	df	SS	*F*	Pr>*F*
Reaction Time				
Main effects:				
SI[a]	1	3403993.16	36.84	0.0001*
Error	39	3603431.02		
SQ[b]	1	627314.63	7.16	0.0108*
Error	39	3415033.29		
FD[c]	1	547735.51	6.66	0.0137*
Error	39	3206158.67		
S-R C[d]	1	78278946.76	107.76	0.0001*
Error	39	28331142.17		
Two-way interactions:				
SI*SQ	1	123849.07	2.12	0.1536
Error	39	2280906.86		
SI*FD	1	31486.12	0.25	0.6190
Error	39	4886236.56		
SQ*FD	1	9836.06	0.06	0.8032
Error	39	6096259.37		
SI*S-R C	1	106425.01	1.69	0.2008
Error	39	2451502.42		
SQ*S-R C	1	232753.16	2.77	0.1041
Error	39	3276922.52		
FD*S-R C	1	23316.82	0.27	0.6075
Error	39	3391848.61		
Three-way interactions:				
SI*SQ*FD	1	952879.72	10.49	0.0025*
Error	39	3543519.71		
SI*SQ*S-R C	1	19481.18	0.34	0.5647
Error	39	2252438.49		
SI*S-R C*FD	1	54593.62	0.57	0.4540
Error	39	3722956.31		
SQ*S-R C*FD	1	8783.81	0.08	0.7766
Error	39	4195115.37		

TABLE VI (continued)

Source	df	SS	F	Pr>F
Four-way interaction:				
SI*SQ*S-R C*FD	1	38486.51	0.49	0.4883
Error	39	3065753.67		

[a] SI = Signal Intensity
[b] SQ = Signal Quality
[c] FD = Foreperiod Duration
[d] S-R C = Stimulus-Response Compatability

TABLE VII

ANALYSIS OF VARIANCE: ACCURACY INITIAL ANALYSIS

Source	df	SS	*F*	Pr>*F*
Accuracy				
Main effects:				
SI[a]	1	3.87	13.24	0.0008*
Error	39	11.41		
SQ[b]	1	0.75	1.26	0.2688
Error	39	23.53		
FD[c]	1	0.17	0.62	0.4367
Error	39	11.11		
S-R C[d]	2	28.30	21.36	0.0001*
Error	78	51.69		
Two-way interactions:				
SI*SQ	1	0.08	0.23	0.6330
Error	39	14.20		
SI*FD	1	0.08	0.20	0.6580
Error	39	16.54		
SQ*FD	1	0.05	0.18	0.6716
Error	39	10.90		
SI*S-R C	2	0.15	0.20	0.8207
Error	78	31.17		
SQ*S-R C	2	1.07	1.69	0.1906
Error	78	24.75		
FD*S-R C	2	0.10	0.16	0.8540
Error	78	26.72		
Three-way interactions:				
SI*SQ*FD	1	1.92	8.02	0.0073*
Error	39	9.36		
SI*SQ*S-R C	2	0.30	0.33	0.7204
Error	78	35.53		
SI*S-R C*FD	2	0.17	0.19	0.8247
Error	78	35.32		
SQ*S-R C*FD	2	2.63	4.10	0.0202*
Error	78	25.03		

TABLE VII (continued)

Source	df	SS	F	Pr>F
Four-way interaction:				
SI*SQ*S-R C*FD	2	0.25	0.46	0.6352
Error	78	22.07		

[a] SI = Signal Intensity
[b] SQ = Signal Quality
[c] FD = Foreperiod Duration
[d] S-R C = Stimulus-Response Compatability

TABLE VIII

ANALYSIS OF VARIANCE: ACCURACY SECOND ANALYSIS

Source	df	SS	*F*	Pr>*F*
Accuracy				
Main effects:				
SI[a]	1	3.30	15.27	0.0004*
Error	39	8.44		
SQ[b]	1	1.60	3.92	0.0547
Error	39	15.90		
FD[c]	1	0.15	0.80	0.3759
Error	39	7.59		
S-R C[d]	1	9.50	18.09	0.0001*
Error	39	20.49		
Two-way interactions:				
SI*SQ	1	0.01	0.02	0.9031
Error	39	16.24		
SI*FD	1	0.22	0.81	0.3724
Error	39	10.77		
SQ*FD	1	0.50	1.93	0.1729
Error	39	10.24		
SI*S-R C	1	0.02	0.10	0.7532
Error	39	9.72		
SQ*S-R C	1	0.15	0.42	0.5184
Error	39	14.34		
FD*S-R C	1	0.10	0.45	0.5059
Error	39	8.65		
Three-way interactions:				
SI*SQ*FD	1	0.90	3.66	0.0632
Error	39	9.60		
SI*SQ*S-R C	1	0.00	0.00	1.0000
Error	39	6.75		
SI*S-R C*FD	1	0.01	0.02	0.8797
Error	39	10.49		
SQ*S-R C*FD	1	0.22	0.88	0.3552
Error	39	10.02		

TABLE VIII (continuued)

Source	df	SS	F	Pr>F
Four-way interaction:				
SI*SQ*S-R C*FD	1	0.15	0.49	0.4865
Error	39	12.34		

[a] SI = Signal Intensity
[b] SQ = Signal Quality
[c] FD = Foreperiod Duration
[d] S-R C = Stimulus-Response Compatability

TABLE IX

REACTION TIME INTERACTION MEANS FIRST ANALYSIS

Source		M	SD
SI - High			
SQ -	No Mask	1460.34	808.75
	Mask	1468.16	759.07
S-R C -	Prior	2103.91	743.78
	Same	807.58	240.62
	Next	1481.25	626.30
FD -	Immediate	1422.52	717.80
	Delay	1505.97	843.54
SI - Low			
SQ -	No Mask	1536.76	788.92
	Mask	1671.47	834.81
S-R C -	Prior	2231.80	791.94
	Same	927.65	324.50
	Next	1652.90	636.41
FD -	Immediate	1571.68	818.29
	Delay	1636.55	810.37
SQ - No Mask			
S-R C -	Prior	2123.56	735.05
	Same	817.24	283.50
	Next	1554.84	662.62
FD -	Immediate	1480.35	778.76
	Delay	1516.74	819.92
SQ - Mask			
S-R C -	Prior	2212.14	802.71
	Same	918.00	291.51
	Next	1579.31	610.52
FD -	Immediate	1513.85	767.45
	Delay	1625.78	835.82

TABLE IX (Continued)

Source	M	SD
FD - Immediate		
S-R C - Prior	2115.12	729.22
Same	832.33	292.45
Next	1543.86	590.96
FD - Delay		
S-R C - Prior	2220.58	806.99
Same	902.91	287.09
Next	1590.30	679.55
SI - High		
SQ - No Mask		
S-R C - Prior	2126.97	746.38
Same	776.63	246.04
Next	1477.41	661.41
FD - Immediate	1471.15	754.07
Delay	1449.53	863.01
SQ - Mask		
S-R C - Prior	2080.85	745.15
Same	838.53	232.50
Next	1485.10	593.28
FD - Immediate	1373.90	679.27
Delay	1562.41	823.34

TABLE IX (Continued)

Source	M	SD
SI - Low		
SQ - No Mask		
S-R C - Prior	2120.16	728.25
Same	857.85	312.86
Next	1632.27	658.84
FD - Immediate	1489.56	805.76
Delay	1583.95	772.19
SQ - Mask		
S-R C - Prior	2343.43	840.64
Same	997.46	322.78
Next	1673.53	616.63
FD - Immediate	1653.80	825.83
Delay	1689.15	846.80
SI - High		
FD - Immediate		
S-R C - Prior	2023.22	640.42
Same	770.07	224.44
Next	1474.28	546.84
FD - Delay		
S-R C - Prior	2184.60	830.71
Same	845.10	251.62
Next	1488.22	700.24
SI - Low		
FD - Immediate		
S-R C - Prior	2207.02	801.89
Same	894.58	337.51
Next	1613.43	627.73
FD - Delay		
S-R C - Prior	2256.57	786.13
Same	960.72	309.53
Next	1692.37	646.51

TABLE IX (Continued)

Source	M	SD
SQ - No Mask		
FD - Immediate		
S-R C - Prior	2135.33	753.86
Same	781.73	259.21
Next	1524.00	518.32
FD - Delay		
S-R C - Prior	2111.80	720.32
Same	852.75	303.34
Next	1585.68	783.00
SQ - Mask		
FD - Immediate		
S-R C - Prior	2094.91	707.90
Same	882.92	315.85
Next	1563.72	658.35
FD - Delay		
S-R C - Prior	2329.37	876.29
Same	953.07	262.26
Next	1594.91	562.39
SI - High		
SQ - No Mask		
FD - Immediate		
S-R C - Prior	2134.55	711.55
Same	785.25	264.92
Next	1493.65	473.39
FD - Delay		
S-R C - Prior	2119.40	788.69
Same	768.02	228.67
Next	1461.17	813.33

TABLE IX (Continued)

Source	M	SD
SI - High		
SQ - Mask		
FD - Immediate		
S-R C - Prior	1911.90	546.87
Same	754.90	177.15
Next	1454.92	617.14
FD - Delay		
S-R C - Prior	2249.80	875.85
Same	922.17	252.52
Next	1515.27	574.68
SI - Low		
SQ - No Mask		
FD - Immediate		
S-R C - Prior	2136.12	803.05
Same	778.22	256.70
Next	1554.35	564.11
FD - Delay		
S-R C - Prior	2104.20	654.88
Same	937.47	345.50
Next	1710.20	740.67
SQ - Mask		
FD - Immediate		
S-R C - Prior	2277.92	804.57
Same	1010.95	370.24
Next	1672.52	687.61
FD - Delay		
S-R C - Prior	2408.95	880.53
Same	983.97	271.28
Next	1674.55	545.35

TABLE X

REACTION TIME INTERACTION MEANS SECOND ANALYSIS

Source			M	SD
SI - High				
	SQ -	No Mask	1127.02	609.08
		Mask	1161.81	553.99
	S-R C -	Same	807.58	240.62
		Next	1481.25	626.30
	FD -	Immediate	1122.18	546.23
		Delay	1166.66	615.74
SI - Low				
	SQ -	No Mask	1245.06	644.34
		Mask	1335.50	596.38
	S-R C -	Same	927.65	324.50
		Next	1652.90	636.41
	FD -	Immediate	1254.01	618.37
		Delay	1326.55	624.45
SQ - No Mask				
	S-R C -	Same	817.24	283.50
		Next	1554.84	662.62
	FD -	Immediate	1152.86	552.69
		Delay	1219.21	696.76
SQ - Mask				
	S-R C -	Same	918.00	291.51
		Next	1579.31	610.52
	FD -	Immediate	1223.32	617.67
		Delay	1273.99	543.10

TABLE X (Continued)

Source	M	SD
FD - Immediate		
S-R C - Same	832.33	292.45
Next	1543.86	590.96
FD - Delay		
S-R C - Same	902.91	287.09
Next	1590.30	679.55
SI - High		
SQ - No Mask		
S-R C - Same	776.63	246.04
Next	1477.41	661.41
FD - Immediate	1139.45	521.85
Delay	1114.60	688.49
SQ - Mask		
S-R C - Same	838.53	232.50
Next	1485.10	593.28
FD - Immediate	1104.91	572.34
Delay	1218.72	532.51

TABLE X (Continued)

Source	M	SD
SI - Low		
SQ - No Mask		
S-R C - Same	857.85	312.86
Next	1632.27	658.84
FD - Immediate	1166.28	584.91
Delay	1323.83	693.48
SQ - Mask		
S-R C - Same	997.46	322.78
Next	1673.53	616.63
FD - Immediate	1341.73	641.78
Delay	1329.26	551.26
SI - High		
FD - Immediate		
S-R C - Same	770.07	224.44
Next	1474.28	546.84
FD - Delay		
S-R C - Same	845.10	251.62
Next	1488.22	700.24
SI - Low		
FD - Immediate		
S-R C - Same	894.58	337.51
Next	1613.43	627.73
FD - Delay		
S-R C - Same	960.72	309.53
Next	1692.37	646.51

TABLE X (Continued)

Source	M	SD
SQ - No Mask		
FD - Immediate		
S-R C - Same	781.73	259.21
Next	1524.00	518.32
FD - Delay		
S-R C - Same	852.75	303.34
Next	1585.68	783.00
SQ - Mask		
FD - Immediate		
S-R C - Same	882.92	315.85
Next	1563.72	658.35
FD - Delay		
S-R C - Same	953.07	262.26
Next	1594.91	562.39
SI - High		
SQ - No Mask		
FD - Immediate		
S-R C - Same	785.25	264.92
Next	1493.65	473.39
FD - Delay		
S-R C - Same	768.02	228.67
Next	1461.17	813.33

TABLE X (Continued)

Source	M	SD
SI - High		
SQ - Mask		
FD - Immediate		
S-R C - Same	754.90	177.15
Next	1454.92	617.14
FD - Delay		
S-R C - Same	922.17	252.52
Next	1515.27	574.68
SI - Low		
SQ - No Mask		
FD - Immediate		
S-R C - Same	778.22	256.70
Next	1554.35	564.11
FD - Delay		
S-R C - Same	937.47	345.50
Next	1710.20	740.67
SQ - Mask		
FD - Immediate		
S-R C - Same	1010.95	370.24
Next	1672.52	687.61
FD - Delay		
S-R C - Same	983.97	271.28
Next	1674.55	545.35

TABLE XI
ACCURACY (PERCENT CORRECT) MEANS
INITIAL ANALYSIS

Source			M	SD
SI - High				
	SQ -	No Mask	93.88	0.665
		Mask	95.13	0.625
	S-R C -	Prior	90.93	0.791
		Same	98.43	0.332
		Next	94.16	0.646
	FD -	Immediate	94.58	0.661
		Delay	94.44	0.631
SI - Low				
	SQ -	No Mask	92.08	0.702
		Mask	92.70	0.751
	S-R C -	Prior	89.37	0.865
		Same	95.83	0.560
		Next	91.97	0.672
	FD -	Immediate	92.70	0.705
		Delay	92.01	0.748
SQ - No Mask				
	S-R C -	Prior	90.41	0.781
		Same	96.56	0.502
		Next	91.97	0.691
	FD -	Immediate	93.33	0.683
		Delay	92.63	0.688
SQ - Mask				
	S-R C -	Prior	89.89	0.876
		Same	97.70	0.426
		Next	94.16	0.626
	FD -	Immediate	94.02	0.688
		Delay	93.81	0.702

TABLE XI (Continued)

Source	M	SD
FD - Immediate		
S-R C - Prior	90.31	0.820
Same	97.18	0.465
Next	93.54	0.663
FD - Delay		
S-R C - Prior	90.00	0.840
Same	97.08	0.469
Next	92.60	0.661
SI - High		
SQ - No Mask		
S-R C - Prior	90.62	0.776
Same	97.91	0.401
Next	93.12	0.687
FD - Immediate	93.33	0.737
Delay	94.44	0.584
SQ - Mask		
S-R C - Prior	91.25	0.810
Same	98.95	0.243
Next	95.20	0.599
FD - Immediate	95.83	0.568
Delay	94.44	0.677
SI - Low		
SQ - No Mask		
S-R C - Prior	90.20	0.790
Same	95.20	0.577
Next	90.83	0.691
FD - Immediate	93.33	0.627
Delay	90.83	0.765

TABLE XI (Continued)

Source	M	SD
SI - Low		
SQ - Mask		
S-R C - Prior	88.54	0.935
Same	96.45	0.544
Next	93.12	0.650
FD - Immediate	92.22	0.777
Delay	93.19	0.727
SI - High		
FD - Immediate		
S-R C - Prior	91.25	0.762
Same	98.12	0.389
Next	94.37	0.710
FD - Delay		
S-R C - Prior	90.62	0.824
Same	98.75	0.265
Next	93.95	0.579
SI - Low		
FD - Immediate		
S-R C - Prior	89.37	0.875
Same	96.25	0.527
Next	92.70	0.613
FD - Delay		
S-R C - Prior	89.31	0.860
Same	95.41	0.594
Next	91.25	0.728

TABLE XI (Continued)

Source	M	SD
SQ - No Mask		
FD - Immediate		
S-R C - Prior	91.87	0.711
Same	96.45	0.544
Next	91.66	0.746
FD - Delay		
S-R C - Prior	88.95	0.841
Same	96.66	0.461
Next	92.29	0.635
SQ - Mask		
FD - Immediate		
S-R C - Prior	88.75	0.910
Same	97.91	0.368
Next	95.41	0.550
FD - Delay		
S-R C - Prior	91.04	0.841
Same	97.50	0.479
Next	92.91	0.689
SI - High		
SQ - No Mask		
FD - Immediate		
S-R C - Prior	91.25	0.816
Same	97.08	0.500
Next	91.66	0.816
FD - Delay		
S-R C - Prior	90.00	0.744
Same	98.75	0.266
Next	94.58	0.525

TABLE XI (Continued)

Source				M	SD
SI - High					
	SQ - Mask				
		FD - Immediate			
			S-R C - Prior	91.25	0.715
			Same	99.19	0.220
			Next	97.08	0.549
		FD - Delay			
			S-R C - Prior	91.25	0.905
			Same	98.75	0.266
			Next	93.33	0.632
SI - Low					
	SQ - No Mask				
		FD - Immediate			
			S-R C - Prior	92.50	0.597
			Same	95.83	0.588
			Next	91.66	0.679
		FD - Delay			
			S-R C - Prior	87.91	0.933
			Same	94.58	0.572
			Next	90.00	0.708
	SQ - Mask				
		FD - Immediate			
			S-R C - Prior	86.25	1.059
			Same	96.66	0.464
			Next	93.75	0.540
		FD - Delay			
			S-R C - Prior	90.83	0.782
			Same	96.25	0.619
			Next	92.50	0.749

TABLE XII

ACCURACY (PERCENT CORRECT) MEANS
SECOND ANALYSIS

Source		M	SD
SI - High			
SQ -	No Mask	95.52	0.579
	Mask	97.08	0.469
S-R C -	Same	98.43	0.332
	Next	94.16	0.646
FD -	Immediate	96.25	0.582
	Delay	96.35	0.471
SI - Low			
SQ -	No Mask	93.02	0.648
	Mask	94.79	0.605
S-R C -	Same	95.83	0.560
	Next	91.97	0.672
FD -	Immediate	94.47	0.579
	Delay	93.33	0.674
SQ - No Mask			
S-R C -	Same	96.56	0.502
	Next	91.97	0.691
FD -	Immediate	94.06	0.666
	Delay	94.47	0.568
SQ - Mask			
S-R C -	Same	97.70	0.426
	Next	94.16	0.626
FD -	Immediate	96.66	0.473
	Delay	95.20	0.607

TABLE XII (Continued)

Source	M	SD
FD - Immediate		
S-R C - Same	97.18	0.465
Next	93.54	0.663
FD - Delay		
S-R C - Same	97.08	0.469
Next	92.60	0.661
SI - High		
SQ - No Mask		
S-R C - Same	97.91	0.401
Next	93.12	0.687
FD - Immediate	94.37	0.692
Delay	96.66	0.432
SQ - Mask		
S-R C - Same	98.95	0.243
Next	95.20	0.599
FD - Immediate	98.12	0.420
Delay	96.04	0.509

TABLE XII (Continued)

Source	M	SD
SI - Low		
SQ - No Mask		
S-R C - Same	95.20	0.577
Next	90.83	0.691
FD - Immediate	93.75	0.643
Delay	92.29	0.654
SQ - Mask		
S-R C - Same	96.45	0.544
Next	93.12	0.650
FD - Immediate	95.20	0.508
Delay	94.37	0.692
SI - High		
FD - Immediate		
S-R C - Same	98.12	0.389
Next	94.37	0.710
FD - Delay		
S-R C - Same	98.75	0.265
Next	93.95	0.579
SI - Low		
FD - Immediate		
S-R C - Same	96.25	0.527
Next	92.70	0.613
FD - Delay		
S-R C - Same	95.41	0.594
Next	91.25	0.728

TABLE XII (Continued)

Source	M	SD
SQ - No Mask		
FD - Immediate		
S-R C - Same	96.45	0.544
Next	91.66	0.746
FD - Delay		
S-R C - Same	96.66	0.461
Next	92.29	0.635
SQ - Mask		
FD - Immediate		
S-R C - Same	97.91	0.368
Next	95.41	0.550
FD - Delay		
S-R C - Same	97.50	0.479
Next	92.91	0.689
SI - High		
SQ - No Mask		
FD - Immediate		
S-R C - Same	97.08	0.500
Next	91.66	0.816
FD - Delay		
S-R C - Same	98.75	0.266
Next	94.58	0.525

TABLE XII (Continued)

Source	M	SD
SI - High		
SQ - Mask		
FD - Immediate		
S-R C - Same	99.19	0.220
Next	97.08	0.549
FD - Delay		
S-R C - Same	98.75	0.266
Next	93.33	0.632
SI - Low		
SQ - No Mask		
FD - Immediate		
S-R C - Same	95.83	0.588
Next	91.66	0.679
FD - Delay		
S-R C - Same	94.58	0.572
Next	90.00	0.708
SQ - Mask		
FD - Immediate		
S-R C - Same	96.66	0.464
Next	93.75	0.540
FD - Delay		
S-R C - Same	96.25	0.619
Next	92.50	0.749

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